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## A Change in Editorship

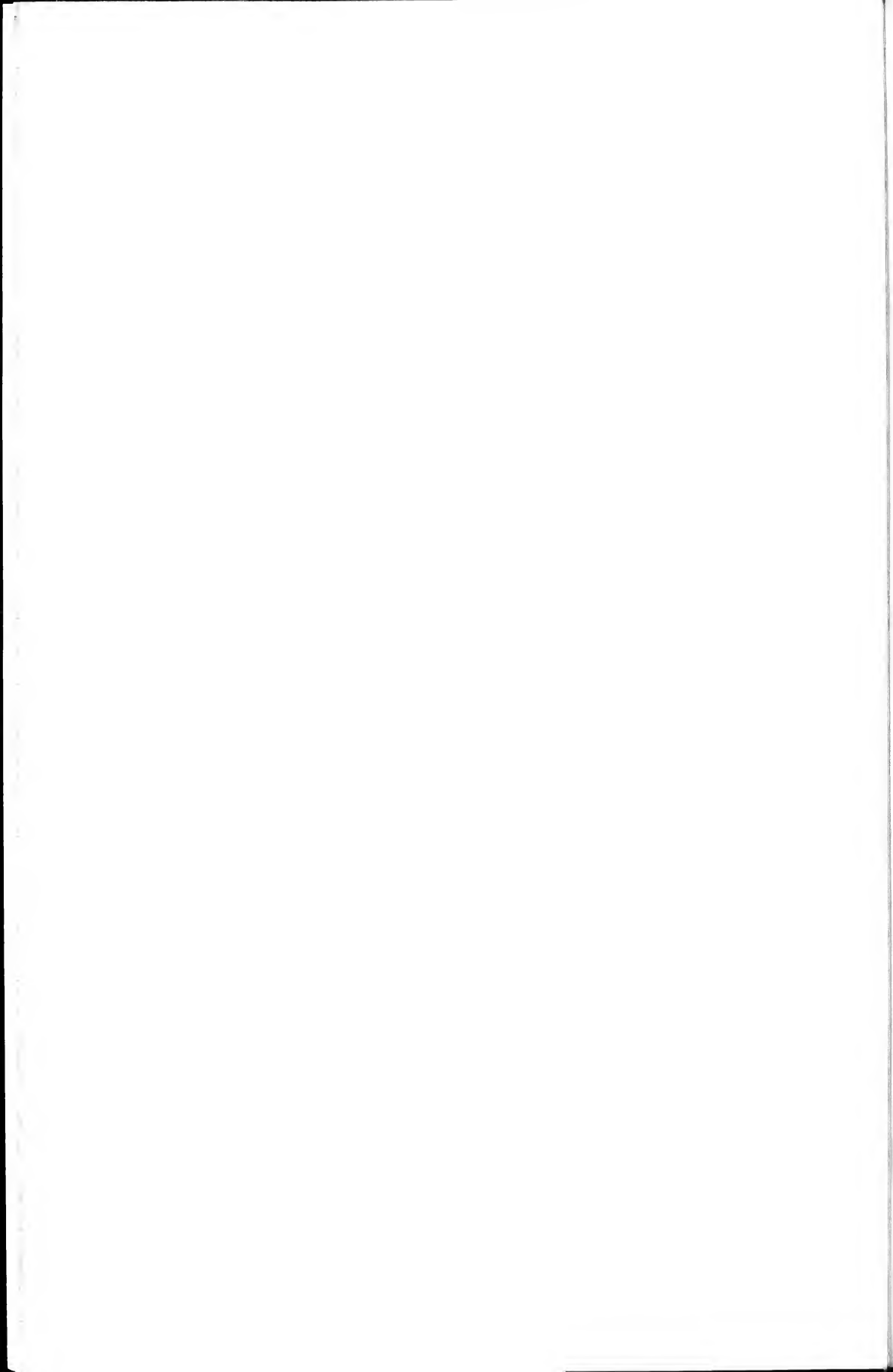
With this issue, a new editor assumes responsibility for the *Journal*. My aims for the *Journal* are threefold:

- *To finish closing the gap in publishing that resulted from events beyond our control four years ago.* By heroic efforts our retiring editor, Professor Thomas E. Smith, brought us within reach of that goal with Volume 88; this double issue represents Nos. 1 and 2 of Volume 89 (2003). We will strive to complete that volume in early 2004, and then to re-establish and adhere to the traditional schedule of four issues per year.
- *To maintain the high quality of published papers* by actively working to increase the number of contributors and peer reviewers of contributed papers.
- *To broaden the scope of the Journal*, taking advantage of our location in the Nation's Capital, to include papers on science and engineering policy, technology assessment, history of science and technology, and closely related fields. We also welcome book reviews on appropriate topics.

The third of those objectives is supported in this issue by a special history of science section consisting of several papers on *Medicine and Myth in the Literature of the Plague Years*. In addition, there are papers from the fields of physical anthropology, sociology, and business economics. We are confident that the upcoming *Capital Science Conference* in May 2004, organized by the Washington Academy of Science and its affiliated societies, will also encourage the flow of first-rate contributed papers to the *Journal*.

We encourage Members and Fellows of the Academy and affiliated societies and all other readers of the *Journal* to send in papers by email to the editor, [vcoates@concentric.net](mailto:vcoates@concentric.net). A revised version of "Instructions to Authors" can be found on our web site, [www.washacadsci.org](http://www.washacadsci.org).

Vary T. Coates



# **Sexual Dimorphism a Proxy for Environmental Sensitivity? A Multi-Temporal View**

**Ann H. Ross, Ph.D.\***

**Lori E. Baker, Ph.D.**

**Anthony B. Falsetti, Ph.D.**

## **Abstract**

Sexual dimorphism in the upper limbs was investigated among skeletal samples from Archaic, Mississippian and contemporary groups. Unexpectedly, the among-group differences suggest that the Archaic sample is less sexually dimorphic than later temporal groups. This is possibly the result of increased activity levels among archaic females. However, in the Mississippian and the later groups, females appear to be more canalized, while males exhibit greater variability.

Historically, physical anthropologists and bioarchaeologists have been concerned with the reconstruction of past life ways and the morphological changes that occur with the transition from one economic strategy to another. Both nutrition and biomechanics have been used to explain postcranial changes observed with different subsistence strategies (Boyd and Boyd, 1989; Frayer, 1989; Larsen, 1984; Ruff et al., 1984; Ruff and Larsen, 1990). Larsen (1984) and Ruff et al. (1984) suggest that a reduction in postcranial size is influenced by nutrition, while shape changes reflect biomechanical modifications associated with behavioral differences. They contend that differential biomechanical loadings due to distinct activities performed by hunter-gatherers and agriculturalists may be used to explain the variation observed in the postcranial skeleton (Bridges, 1985, 1989; Bridges et al., 2000; Ruff et al., 1984). Furthermore, diminished within-group sexual dimorphism is expected in agricultural societies as a consequence of a reduction in repeated biomechanical loadings with the transition to maize agriculture than in pre-agricultural populations. Ruff (1987) attributes the reduction of sexual dimorphism in the cross-sectional area of the femur from pre-agricultural

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to agricultural populations to a reduction of biomechanical loading of male femora as a result of decreased mobility and increased sedentism. Greater environmental sensitivity for males is another factor used to explain increased levels of within-group sexual dimorphism. Namely, females are thought to be more buffered against environmental stresses than males due to their need to support pregnancy and lactation (Stini, 1975, 1982). Reduced arm muscle sexual dimorphism has been observed by many in non-European groups (Black and coworkers, 1977; Bogin and McVean, 1981a,b). In their study of Kayapo Indians from Brazil, Black and colleagues (1977) conclude that reduced arm sexual dimorphism is not due to greater nutritional stress experienced by Kayapo males, but rather to increased muscular development of Kayapo females as a result of strenuous physical labor.

The objectives of this investigation are twofold: 1) to explore the variation of sexual dimorphism in the forearm; and 2) to determine the degree of sexual dimorphism in the ulna and radius among groups of different temporal periods, Middle to Late Archaic (5000-500 BC), Mississippian (900-1450 AD), and contemporary populations, and if it can be attributed to either biomechanical loading or environmental sensitivity (e.g. nutrition, disease) models.

## Materials and Methods

### *Samples*

The Archaic sample totals  $N=49$  (females  $n=32$ ; males  $n=17$ ), and includes the Eva (6BN12), Kays Landing (15HY13), and Big Sandy (25HY18) sites from East Tennessee. The Mississippian sample consists of  $N=36$  (females  $n=24$ ; males  $n=12$ ) and is comprised of the Mouse Creek (3MN3, 4MN3), and Toqua (40MR6) sites from West Tennessee. The archaeological material is curated at the McClung Museum at the University of Tennessee, Knoxville. The contemporary samples include  $N=142$  American whites (females  $n=46$ ; males  $n=96$ ) and American blacks consisting of  $N=128$  (females  $n=50$ ; males  $n=78$ ), which were obtained from the Forensic Databank housed at the University of Tennessee, Knoxville.

### *Measurements*

Standard osteological measurements were collected for both ulnae and radii as described in Moore-Jansen et al. (1994). The left element was used when available, however, when the left was not present the right was substituted. The measurements included are the dorso-volar and transverse diameters of the ulna and sagittal and transverse diameters of the radius. Ulnae and radii lengths were collected but were not included in the analysis because diaphyseal lengths are believed to be more responsive to environmental variations (Jantz and Owsley, 1984).

### Statistics

Size and shape variables are computed according to Mosimann and colleagues (Mosimann and James 1979; Darroch and Mosimann 1985) using raw measurements. Size is defined as the geometric mean of all variables. The size variable for the four long bone measures is calculated as follows:

$$\text{SIZE} = (\prod_{i=1}^n X_i)^{1/n}$$

The new shape variables are simple ratios of the geometric mean, and are thus dimensionless.

A one-way analysis of variance (ANOVA) was performed on the SIZE variable to test the null hypothesis that the mean size is not significantly different among the groups. A canonical discriminant analysis was then performed on the new shape variables to extract canonical variates, which are linear combinations of predictor variables that summarize between-population variation. The differences are graphically represented on canonical axes. The canonical axes are selected to maximize population differences. In addition, a Pearson's correlation coefficient was calculated to test the relationship between the original size and shape variables and their canonical variate scores. The degree of differentiation among the groups was measured using a Mahalanobis  $D^2$  or generalized distance, which is a function of the group means and the pooled variances and covariances (Afifi and Clark, 1996).  $D^2$  is used to test whether group centroids are significantly different. The statistical tests were conducted using the SAS PC package (2000).

### Results

Descriptive summary statistics for both raw and shape variables for each population are presented in Table 1. The ANOVA for size yielded significant differences among the groups (R-square 0.2572;  $\text{Pr} > F$  0.0001). The  $D^2$  values are presented in Table 2. There are significant differences between centroid means among the groups. Surprisingly, Archaic females and males are not significantly different from each other, whereas American white males are the furthest removed. However, American white females, American black females and Mississippian females are not significantly different from each other.

Three significant canonical axes were extracted for the transformed shape variables and are presented in Table 3, while the total canonical structure for CAN1, CAN2, and CAN3 are reported in Table 4. The first canonical axis accounts for approximately seventy-one percent of the among-group variation, while approximately seventeen percent is accounted for on CAN2, and eight percent on CAN3. The first canonical axis separates the groups with respect to transverse radial shape and dorso-volar shape, whereas the second axis isolates the groups on sagittal and transverse radial shape (Figure 1). Interestingly, Archaic females have relatively more robust interosseous crest development than American

White females, American Black females, and Mississippian females. The reverse is true for transverse radial diameters. Unexpectedly, the Archaic populations are the least sexually dimorphic group followed by American Blacks, American Whites, and Mississippians. The variation observed among the groups along CAN3 is consistent with anatomical variations observed along CAN1 (i.e. groups that have robust ulnar interosseous crest development will have small transverse ulnar development (see Figure 2). The Pearson's correlation coefficients show that the variation observed among the females is correlated to differences in shape rather than size. Males, conversely, demonstrate both shape and size related variation for CAN1 and CAN3 (Table 5).

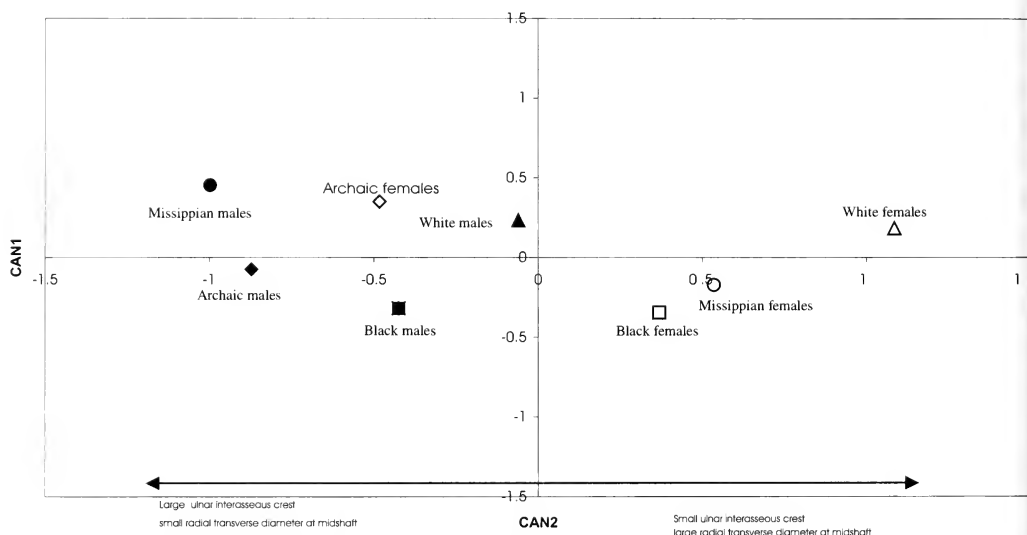


Figure 1. Class Means on Canonical Variates for CAN1 and CAN2.

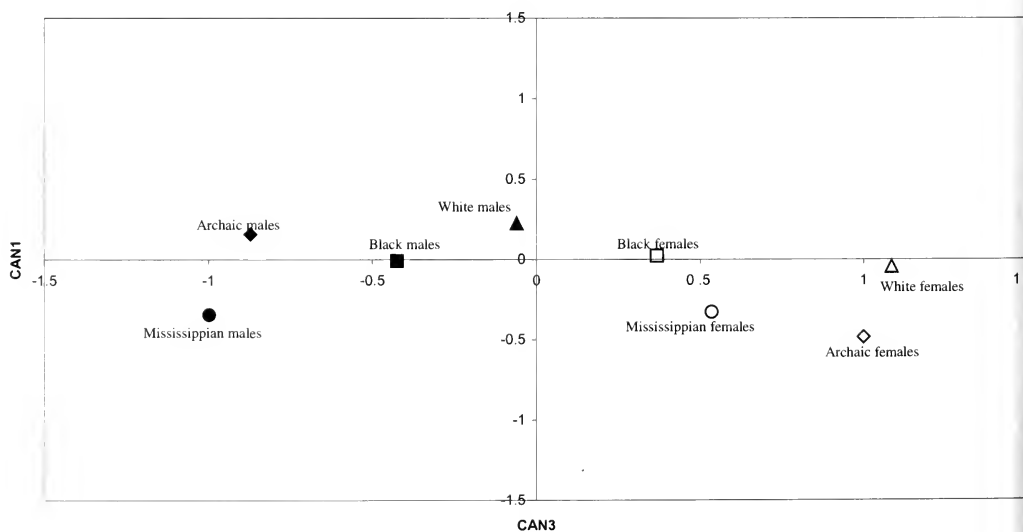


Figure 2. Class Means on Canonical Variates for CAN1 and CAN3.

### Interpretation and Conclusions

The results of this study show that forearm variation in females is solely related to shape differences rather than size differences. However, the variation observed in males across all time periods is related to both size and shape. Ulnar and radial shape are similar in black, white, and Mississippian females. Thus, there is an increase in size-related sexual dimorphism over time and across subsistence strategies. Shape-related sexual dimorphism shows a different trend entirely, it increases between the Archaic and Mississippian time periods and shows a decrease between Mississippian and more contemporary groups. The Mississippian sample exhibits the most shape-related sexual dimorphism. This variation in shape-related sexual dimorphism suggests that Mississippian males and females are performing different tasks possibly due to sexual division of labor observed with the transition to maize agriculture.

Levels of sexual dimorphism have been used to ascertain environmental stress. Because male growth is more influenced by environmental stress than female growth, some researchers have reasoned that differences between males and females should be less in stressed or marginalized environments (Greulich, 1951; Greulich et al., 1953; Stini, 1972, 1975; Tanner, 1962; Tobia, 1972). The reduction of environmental stress associated with contemporary societies is a plausible explanation for the high degree of size-related sexual dimorphism observed in the contemporary sample when compared to earlier groups. However, this hypothesis does not adequately explain the variation of shape-related sexual dimorphism observed in the Mississippian group, nor does it adequately explain the low level of overall sexual dimorphism observed in the Archaic sample. Although, it could explain why Mississippian and contemporary females stay roughly the same size and shape through time while Mississippian and contemporary males change.

The interosseous crests of the ulna and radius exhibit the greatest area of development in Archaic males and females, and in Mississippian males. The interosseous membrane connects the radius and ulna and provides attachments for the deep forearm muscles (Grays, 1995). The forearm muscles that attach to the interosseous membrane at the area of greatest development on the radius are: flexor pollicis longus, pronator teres, extensor pollicis brevis; and on the ulna: flexor digitorum profundus, abductor pollicis longus, extensor pollicis longus, and extensor indicis. These muscles aid in supination and pronation of the forearm, and extension, flexion, and abduction of the fingers. This area of greatest development observed in Archaic males and females and in Mississippian males is probably a result of continuous and prolonged use by performing activities that require pronation and supination of the forearm.

Greater forearm muscle development due to physical labor rather than environmental stress could account for the low level of sexual dimorphism observed in the Archaic sample. Archaic females appear to be engaging in physical activities that increase forearm robusticity (i.e., interosseous crest development). Furthermore, Mississippian males are engaging in physical activities that produce greater development of the forearm than Mississippian females. The results of this study concur with Stinson (1985), that activity is a significant

factor and a plausible explanation for the reduction of shape-related sexual dimorphism. Thus, caution should be exercised when interpreting levels of sexual dimorphism solely as a result of environmental sensitivity.

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Appendix

Table 1. Descriptive summary statistics.

Archaic females					
Variable	N	Mean	Std Dev	Min	Max
Saggital rad.	33	9.4545	0.9712	8	12
Transv.rad.	33	12.3333	1.6329	9	17
Dorso-volar ul.	36	11.3056	0.9508	9	13
Transverse ul.	36	13.2222	1.6581	11	18
Size	32	11.4940	0.9838	9.72	13.8188
Sagshape rad.	32	0.8251	0.0680	0.7073	1.0241
Tranvshape rad.	32	1.0728	0.0956	0.8651	1.2853
Dorso-volar shape	32	0.9857	0.0564	0.8677	1.1067
Tranvshape ul.	32	1.1584	0.0755	1.0241	1.4157
Archaic males					
Variable	N	Mean	Std Dev	Min	Max
Saggital rad.	18	11.1666	1.2948	9	15
Transv.rad.	18	13.3333	1.6088	11	17
Dorso-volar ul.	20	12.9000	1.3727	11	15
Transverse ul.	20	14.3500	1.3089	11	17
Size	17	12.8298	0.8329	11.6233	14.3221
Sagshape rad.	17	0.8733	0.1098	0.7680	1.1842
Tranvshape rad.	17	1.0389	0.0906	0.9372	1.2302
Dorso-volar shape	17	1.0121	0.0669	0.8684	1.0994
Tranvshape ul.	17	1.1095	0.0784	0.9385	1.2496
American black females					
Variable	N	Mean	Std Dev	Min	Max
Saggital rad.	50	10.96	1.0294	9	14
Transv.rad.	50	14.18	1.4241	12	17
Dorso-volar ul.	50	11.48	1.2974	10	16
Transverse ul.	50	15.22	1.6073	11	18
Size	50	12.8025	0.9110	10.4401	15.1309
Sagshape rad.	50	0.8560	0.0497	0.7400	1.0086
Tranvshape rad.	50	1.1079	0.0794	0.8645	1.2621
Dorso-volar shape	50	0.8966	0.0756	0.7845	1.2103
Tranvshape ul.	50	1.1886	0.0937	0.8875	1.3978

Table 1 continued.

*American black males*

Variable	N	Mean	Std Dev	Min	Max
Sagittal rad.	78	13.6282	1.2285	10	17
Transv.rad.	78	16.4744	1.9852	11	20
Dorso-volar ul.	78	15.1282	1.7754	11	21
Transverse ul.	78	18.0897	2.3587	12	22
Size	78	15.6819	1.1772	12.9449	18.6492
Sagshape rad.	78	0.8705	0.0679	0.7457	1.0989
Tranvshape rad.	78	1.0493	0.0884	0.8143	1.2750
Dorso-volar shape	78	0.9661	0.1041	0.8230	1.3711
Tranvshape ul.	78	1.1517	0.1066	0.8242	1.3153

*Mississippian females*

Variable	N	Mean	Std Dev	Min	Max
Sagittal rad.	25	10.24	0.9256	9	12
Transv.rad.	25	13.52	1.5843	11	16
Dorso-volar ul.	24	11.125	1.0759	9	13
Transverse ul.	24	14.8333	1.8572	11	19
Size	24	12.2891	0.7871	11.0390	14.3524
Sagshape rad.	24	0.8387	0.0696	0.7097	1.0050
Tranvshape rad.	24	1.1086	0.1016	0.9330	1.2987
Dorso-volar shape	24	0.9052	0.0658	0.7305	1.0252
Tranvshape ul.	24	1.2058	0.1185	0.9212	1.4773

*Mississippian males*

Variable	N	Mean	Std Dev	Min	Max
Sagittal rad.	12	11.5833	1.0836	9	13
Transv.rad.	12	14.5833	1.3114	13	17
Dorso-volar ul.	15	14.20	1.3732	11	16
Transverse ul.	15	16	1.5584	13	18
Size	12	13.9868	1.0213	11.3731	15.3942
Sagshape rad.	12	0.8275	0.0371	0.7715	0.8848
Tranvshape rad.	12	1.0443	0.0802	0.9508	1.1923
Dorso-volar shape	12	1.0250	0.0701	0.9118	1.1702
Tranvshape ul.	12	1.1369	0.0607	1.0240	1.2103

Table 1 continued.

American white females					
Variable	N	Mean	Std Dev	Min	Max
Saggital rad.	46	10.4348	1.2230	9	15
Transv.rad.	46	14.5870	1.7836	10	18
Dorso-volar ul.	46	11.3261	1.7263	9	15
Transverse ul.	46	14.7826	2.0211	9	20
Size	46	12.5706	1.0834	11.0889	16.0464
Sagshape rad.	46	0.8304	0.0704	0.7471	1.1959
Tranvshape rad.	46	1.1618	0.1201	0.7973	1.4942
Dorso-volar shape	46	0.9004	0.1108	0.7195	1.2793
Tranvshape ul.	46	1.1753	0.1191	0.9676	1.3357

American white males					
Variable	N	Mean	Std Dev	Min	Max
Saggital rad.	96	12.9375	0.9713	10	15
Transv.rad.	96	17.0417	1.1782	11	21
Dorso-volar ul.	96	14.6458	1.7887	11	21
Transverse ul.	96	17.3437	2.3878	12	23
Size 96	15.3271	1.1211	12.5428	17.6488	
Sagshape rad.	96	0.8451	0.0438	0.7472	0.9947
Tranvshape rad.	96	1.1110	0.0759	0.8417	1.2967
Dorso-volar shape	96	0.9572	0.1129	0.8027	1.3008
Tranvshape ul.	96	1.1294	0.1106	0.8235	1.3698

Table 2. Mahalanobis  $D^2$  matrix.

From group	Archaic	Archaic	Am. Black	Am. Black	Miss.	Miss.	Am. White	Am. White
Archaic	0							
Archaic	0.6876*	0						
Am. Black	1.3548§	1.8464«	0					
Am. Black	0.5965§	0.3053	0.7385«	0				
Miss.	1.3131	2.2996«	0.2168	1.0633«	0			
Miss.	0.2785	0.6218	2.6732*	1.0556§	2.7408«	0		
Am. White	2.6541*	3.9415*	0.9673«	2.5399*	0.5587	4.5503*	0	
Am. White	0.5106§	0.8498§	0.5864«	0.5191«	0.8268§	1.2500§	1.4513*	0

P-value &lt; \*0.0001, «0.001, §0.05

Table 3. Significant canonical axes.

Canonical	Eigenvalue	Proportion	Likelihood Ratio	Approx. F	Num. DF	Pr > F
1	0.3303	0.7068	0.6580	5.46	28	<.0001
2	0.0801	0.1715	0.8754	2.61	18	0.0003
3	0.0377	0.0806	0.9456	1.96	10	0.0346

Table 4. Total canonical structure.

Variable	CAN1	CAN2	CAN3
Saggital rad.	-0.2124	-0.7379	0.5336
Transverse rad.	0.7187	0.5057	0.3485
Dorso-volar ul.	-0.6799	0.4279	0.0061
Transverse ul.	0.3175	0.3892	-0.7541

Table 5. Pearson Correlation Coefficients.

Females	Sagshape rad	Tranvshape rad	Dorso-volar shape	Tranvshape ul.	Size
CAN1	-0.2214 (0.0061)	0.7539 (<.0001)	-0.6605 (<.0001)	0.1960 (0.0155)	0.1312 (0.1071)
CAN2	-0.7674 (<.0001)	0.5719 (<.0001)	0.4078 (<.0001)	-0.3854 (<.0001)	-0.07367 (0.3670)
CAN3	0.5364 (<.0001)	0.3799 (<.0001)	-0.0250 (0.7598)	-0.8094 (<.0001)	-0.0651 (0.4258)
Males					
CAN1	-0.1393 (0.0475)	0.6508 (<.0001)	-0.6971 (<.0001)	0.3631 (<.0001)	0.2244 (0.0013)
CAN2	-0.7288 (<.0001)	0.4713 (<.0001)	0.4639 (<.0001)	-0.4039 (<.0001)	0.0166 (0.8137)
CAN3	0.5194 (<.0001)	0.3829 (<.0001)	-0.0207 (0.7696)	-0.7074 (<.0001)	-0.1426 (0.0424)

(P-value).



# Decision Making in a High Speed World: An Early Warning System for Avoiding Crises

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## Abstract

Crisis management comes more naturally than managing to avoid crises because change can be so disruptive as to tear organizations apart. In this paper we suggest that:

1. humankind has entered an era in which events unfold with unparalleled speed
2. the speed of evolution will accelerate further.

In today's complex societal systems, the time of warning and decision is getting shorter and unless we modify our models of thinking by using new cognitive tools, such as 'images of the future,' any kind of algorithm applied to the present informational space is bound to fail when used to forecast change.

## Introduction: Enron's Collapse or Chaos Theory Revisited

Economists and historians have been taking change and disruptions seriously for decades. Joseph Schumpeter coined the term 'creative destruction' to explain how advances in technology, often small ones, can overturn the powers of established companies. The ontological view has been presented by Karl Popper's argument that logically present knowledge cannot know the contents of radically new knowledge. At a societal level, the first rigorous acknowledgment of the increasing speed of human existence has been put forward in a landmark paper published by Mircea Eliade, probably the world's most renowned scholar of comparative religions [1]. Writers such as Milan Kundera paid great attention to 'societal speed,' and have used very imaginative artistic ways to portray it: "the degree of speed is directly proportionate to the intensity of forgetting" [2]. More and more eminent scholars have embarked on the journey to tame the speed of evolution, especially after the advent of catastrophe theory, and later, chaos theory. Chaos can be important

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because its presence means that long-term predictions are worthless and futile [3]. Scholars have warned that coping with change will become “the most severe test that history has placed on human psychology” [4].

Ten years ago we stated that “it is dangerous to speed up information in systems that hold great potential of surprise, because not much is known about their deeper, fundamental pattern” [5]. History has quickly validated the above proposition. Witness Enron’s collapse. Enron was not just an energy company. It exhibited all the characteristics of chaos systems, as outlined with analytical acumen and intellectual integrity by Williams Garnett [3]. It was also the icon of management writers who emphasize radicalism over incremental change and creativity over control.

The books of various business gurus have singled out Enron as a paragon of good management, for *Leading the Revolution* [6], practicing *Creative Destruction* [7], devising *Strategy as Structured Chaos* [8], and winning the *War for Talent* [9]. McKinsey, the consulting firm that employs both Mr. Foster and Mr. Michaels and counts Jeff Skilling, the former Enron chief executive, among its alumni, has a practice dedicated to the ‘creative destruction’ thesis.

But since Enron has filed for bankruptcy, the second largest US company ever to do so, three questions arise. Firstly, should these consultants and academics have been more critical in their thinking about the Houston-based energy trader? Secondly, does Enron’s fall confirm the late MIT economics Professor and Nobel Prize Laureate Franco Modigliani’s view that ‘perception is everything’?

And thirdly, can any company base its long-term strategy, as Enron did, on the premise of radical innovation? Professor Hamel’s best-selling book argued that to succeed, businesses need to do more than deliver incremental improvements to products or processes. Enron was an example of a ‘grey-haired revolutionary’: an established company that innovated with such success that it transformed its industry.

The company’s single-handed creation of a competitive market in natural gas trading—and its later moves into power plant development, broadband telecommunications and the online trading of power—were painted as an exemplary blend of entrepreneurial spirit backed by financial muscle. Professor Hamel wrote: “As much as any company in the world, Enron has institutionalized a capacity for perpetual innovation ... (it is) an organization where thousands of people see themselves as potential revolutionaries” [6].

The snag is that business revolutions are very difficult to control. Failure of control was at the heart of Enron’s sudden fall from grace. The company’s senior officers created a capital structure that exposed it to risks that were systematically hidden from shareholders and, finally, led to criminal charges against the perpetrators of such fictitious off-balance sheet entities.

Even before the collapse of Enron, the 'revolutionize or die' school of management thinking was facing growing opposition. In July 2000, Eric Abrahamson, a management professor at Columbia Business School in New York, argued that companies should aim for 'dynamic stability' rather than constant change [10]. In February 2001, Peter Brabeck, chief executive of Nestle, went further: "All this talk about reinvention in business reminds me of 1968, when a whole generation thought you couldn't have social change without revolution. I hope we are past that now because it doesn't make sense. Not for society, not for business. Evolution can happen if you believe in it" [11].

Jim Collins, a management writer and former Stanford professor, has emerged as the exemplary figure for this gradualist school of thought. The emphasis on incremental change is not just a reaction to the work of Hamel, Foster *et al.* It is also based on hard data. In *Good to Great*, Collins examines the management methods used by established companies that went on to deliver stellar long-term returns to shareholders. According to Collins, "revolutionary results do not come through revolutionary processes." "Revolution can look as if it is delivering results in the short term—like steroids for an athlete—but there is a long-term danger to health. If you want to build a meaningful track record over 15 years or more, the last thing you want is a business revolution." [12]

### **Societal Speed, Algorithms and Incomplete Information**

Given that the speed of evolution is accelerating in an unprecedented manner, 'early warning systems' have become more and more important. Witness the 2001 U.S. recession which has taken policy makers by surprise: the same technological forces that have led to a resurgence in the growth rate of labor productivity, or output per hour, have also made the economy more prone to abrupt downturns. Because businesses can now monitor demand for their products minute by minute, they can adjust their own output almost instantaneously by reducing inventories of unsold goods and unused supplies.

And because they can see better what is happening across the economy, different businesses and industries increasingly tend to respond in concert to the same data. The result is not only a faster adjustment, but one that is potentially more synchronized, compressing changes into an even shorter time frame. This very rapidity with which the current adjustment is proceeding raises another concern, of a different nature.

While technology has quickened production adjustments, human nature remains unaltered [13]. "We respond to a heightened pace of change and its associated uncertainty in the same way we always have. We withdraw from action, postpone decisions and generally hunker down until a renewed, more comprehensible basis for acting emerges." (Esther Dyson has called this phenomenon 'the retreat to the present'.) When we also factor in the fact that the key variable within human decision making remains

the inelastic attention span of the decision maker [14], we realize why, in present complex societal systems, knowing the proper 'time of warning and decision' is critical in avoiding crises, i.e., sudden, undesirable and irreversible events of great magnitude.

There still are policy makers who think that if they had an appropriate database, the measuring and modeling of a fast-paced economy would be easier. [15] In other words, they believe that because product cycles are truncated by rapid innovation, the 'real time' measurement of detailed micro-level products' characteristics would solve the problem. They like to provide examples supporting this view.

One of these examples is the prolonged statistical neglect of the cell phone. Cell phones were a staple in almost three million US households as early as 1992. But cell phones were not reflected in the US Consumer Price Index (CPI) until 1998, when U.S. citizens bought almost 35.5 million of them. That was largely because the market-basket was still locked into an outdated formula that had counted telephone service in the costs of housing—and cell phones were used outside the home. [16] We consider that a more updated database of goods and services will not deal with the root of the problem. *Our cognitive concepts are the key, not better databases.*

Reading of reality goes beyond databases. If the ongoing and emerging processes we are witnessing today are bringing about the most radical rupture in continuity, [17] the challenge is a new paradigm in decision making, a paradigm that might start by acknowledging that we gather data from an informational environment that seems familiar but basically is incomplete. And, as we mentioned elsewhere, [5] "any kind of algorithm applied to incomplete information is bound to fail when used to forecast socio-economic change." Professor Linstone reached a similar conclusion when he observed that "knowledge of the real world cannot be satisfactorily attained by means of the world of mathematics *as it exists today*." [18]

### Why Do We Need Early Warning Indicators?

The need for early warning indicators comes both from the fact that the past is not a good predictor of the future and also from the fact that the speed of technical and societal change tends to invalidate or drive into obsolescence the most elaborate forecasts. Robert Barbera, chief economist at Hoenig & Company, an investment firm in Port Chester, New York, argues that "many forecasters forecast the recent past." Bill Joy, former chief scientist at Sun Microsystems, estimates that "as much as 20 per cent of the company's technical knowledge becomes obsolete each year."

That's why, in the recent years, the process of devising and implementing 'early warning indicators' has intensified. Witness the recent work on early warning systems for currency crises [19] and for financial system crises. [20] No less than the IMF Managing Director, Horst Kohler, recently pointed out that "we need to have a process of early warning based on sound professional advice." [21]

Most importantly, probably, was the ingenuity to develop an Early Warning System in the field of accounting and financial statements analysis by Charles Mulford and Eugene Cominsky. [22] The authors examine the results of a survey of bankers and develop a remarkable system for rating earnings' upside and downside risk potential. They call it the 'Earnings Reversal Score,' which concisely categorizes cautionary signals, such as profitability, liquidity, and management-related early warnings, enabling accountants to recognize problems and suggest timely corrective measures to managers.

'Earnings shortfalls' are material differences between a corporation's expected and actual earnings. They spell big troubles—Enron is a case in point—for lenders and equity investors, to say nothing of the company in question. The failure to anticipate an 'earnings surprise' can threaten a lender's prospects for loan repayment, cause shareholders to absorb heavy losses and, ultimately, may lead to the respective company's bankruptcy.

The early warning system's approach has gained tremendous ground in the last few years, when the speed with which events started to unfold made other forecasting models less reliable. The reasons are threefold. Firstly, in most econometric models crucial input factors are omitted and so occasionally outputs miss by a mile. Often, for something closer to the truth we have to seek out obscure newsletters and websites. For example, as a group, Wall Street economists have failed to predict any of the three recessions in the last 20 years, according to records kept by the Federal Reserve Bank of Philadelphia. Secondly, to quote Alan Greenspan, Federal Reserve Board chairman, "the future, at root, cannot be foretold." [14] Thirdly, "we are increasingly facing the *inconceivable*, something radically different from *uncertainty*." [16] Here, *inconceivable* is defined as a "mutative set of processes that produce overall phase jumps." (For the taxonomy and examples of phase jumps, as well as for a useful indicator on how to identify discontinuity, see [23]).

Since, almost by definition, the impact of disruption comes as a surprise, even in these times of economic caution, its complexity and potency demand new strategies, for disruption can never be avoided or eliminated. [24] The main idea behind the Early Warning Indicators approach is that: more than *uncertainty*, *inconceivable* matters. For example, in many of the issues that concern policy makers, there is an important distinction between *mean* and *variance*.

Indeed, forecasting is much more than just giving the central cases; when we forecast, we should describe the probability distribution of all the possible outcomes. However, most forecasts give single estimates that convey little information. The more sophisticated offer a range. The best are set in terms of probabilities of different events occurring. A 50% chance of deep recession next year provides more useful information for business and policy makers than a prediction of 1% real growth.

The Early Warning Indicators (EWI) system relies on monitoring critical variables relevant for the specific industry or firm. Thus EWI prepares businesses to face the turning points by having drawn up open-ended contingency outlooks and elastic scenarios to cope with crises, crashes, catastrophes (that is, with the *inconceivable*, rather than with mere *uncertainty*). Given the speed with which events unfold in today's world, companies that rely solely on forecasting techniques based on past patterns are unable to predict the downside or upside risks to their businesses.

After years of contemplating the way businesses truly operate, I started applying the Early Warning Indicators (EWI) in real—that is, no longer simulated—situations. This is consistent with the fact that business executives, in contrast with the policy makers at a macro level, do have to make decisions in real time, preemptively—that is before they gather and process all the information—rather than just reacting to market dynamics. They have to deal almost constantly with the overarching issue of incomplete information.

### **Strategic Positioning of Firms in Mature Technological Industries: a Case Study**

However, before applying EWI to a real world situation, one needs to turn to the analytical framework developed by Michael E. Porter in his classic book on competitive strategies [25], in order to deduce what would be the best strategic positioning of companies. This is because we draw from the example of a company operating in a technologically mature industry, namely in the U.S. steel service sector. For the sake of simplicity, we shall name this firm 'SW Co.' SW Co. represents the typical case of a very competitive U.S. manufacturing firm, its strengths and weaknesses making it an almost perfect example of how the U.S. industry reacted in the late 1990s and early 2000s to new business challenges and to the main technological trends. The customers' request for SW Co.'s high value-added products is about 20% of the total range of the company's products, while the request for medium value-added products is 40% and for low value-added products also 40%.

Since SW Co. operates in a fragmented industry, one of its features is the less than strong bargaining position with buyers. The main result of this rather weak position is that the company is—to use Porter's terminology—'stuck in the middle.' In other words, it tends either to lose the high-volume customers who demand low prices or must bid away its profits to get this business away from low-cost firms. Yet, SW Co. tends also to lose high-margin businesses—the cream—to the firms which are focused on high-margin targets or have achieved differentiation overall. Thus, SW Co. is almost guaranteed low profitability. So SW Co. is supposed to make a fundamental strategic decision.

Either it must take the steps necessary to achieve cost leadership or at least cost parity, which usually involves aggressive investments to modernize and to buy market share by acquiring downstream operations, or it must orient itself to a particular target

or achieve some uniqueness (product differentiation). The choice among these options is necessarily based on the firm's capabilities and limitations. Successfully executing one of the above-mentioned strategies involves different resources, strengths, organizational arrangements, and managerial style. The strategy that probably suits the company the best is the first one: achieve cost leadership through aggressive investments to modernize and buy market share.

When exit barriers are high—U.S. steel industry—excess capacity does not leave the industry, and companies that lose the competitive battle do not give up. Rather, they grimly hang on and, because of their weakness, have to resort to extreme tactics. The profitability of the entire industry can be persistently low as a result.

The best case from the viewpoint of industry profits is one in which entry barriers are high but exit barriers are low. Here entry will be deterred, and unsuccessful competitors will leave the industry. When both entry and exit barriers are high, profit potential is high but is usually accompanied by more risk (SW Co.'s market for high value-added products). The case of low entry and exit barriers is merely unexciting, but the worst case is one in which entry barriers are low and exit barriers are high (SW Co.'s market for low value-added products). Here entry is easy and will be attracted by upturns in economic conditions or other temporary windfalls. However, capacity will not leave the industry when results deteriorate. As a result, capacity stacks up in the industry and profitability is usually chronically poor.

If ranked on a technical capabilities scale (with '0' meaning lack of technical capabilities and '100' maximum technical capabilities), SW Co. will probably enjoy a score of around 80. On the other hand, if ranked on a weak/moderate/strong/very strong-based scale, the competition for the company's low value-added products can be ranked as weak, for medium value-added as moderate and for high value-added as strong (not in terms of volume but in terms of profitability). Given the present business environment, it is expected that competition will increase in all three categories (low-, medium-, and high-value added). Regarding high value-added processes, in 1994 there were only three *temper pass cut-to-length* lines in the United States, (out of which one was owned by SW Co.); now there are no fewer than 16.

The only sensible business strategy for SW Co. is to achieve overall cost leadership through aggressive investments to modernize and buy market share by acquiring downstream operations. The basic economic rationale behind this decision is that an increase in SW. Co.'s market share would lead to a rise in its return on investment.

Cost leadership requires cost minimization in areas like service, sales force, and so on. A great deal of managerial control to cost control is necessary to achieve these aims. Low cost relative to competitors should become the theme running through the entire strategy, through quality, service, and other areas. In this respect, benchmarking for costs, sales, purchases and inventory is crucial.

These benchmarks should translate into simple targets in order to become effective management tools. If these targets are not implemented, then cost control becomes void of its meaning. The timing for adopting the new business strategy is favorable since now SW Co. can buy cheap assets as a result of other companies' financial distress.

We also need to point out the main risks associated with such a strategy. Cost leadership imposes severe burdens on the firm to keep up its position, which means reinvesting in modern equipment, outsourcing constantly, ruthlessly scrapping obsolete assets, avoiding product line proliferation and being alert to technological improvements. Cost declines with cumulative volume are by no means automatic, nor are reaping all available economies of scale achievable without significant attention. Last but not least, SW Co. needs to identify and recognize industry trends early. For example, in the near future it is expected that new exogenous industry trends will lead to consolidation and rationalization of assets by altering the causes of fragmentation.

### **Total Factor Productivity Growth Trend**

Based on the formula developed by Shlomo Maital and Hariolf Grupp [26], we have computed SW Co. total factor productivity (TFP). When one subtracts 'contribution of capital' from 'change in labor productivity' the result is called Total Factor Productivity: the change in the productivity of labor and capital, generated without capital investment (such as: better management methods, etc.). The change in TFP is especially important, because it goes straight to the bottom line.

It enables higher output and sales without spending more money on labor and without borrowing and investing more capital. This is why analysis of annual change in TFP is a powerful underlying driver of performance and profitability. TFP shows how much value added a typical worker, plus the tools, IT and equipment he or she uses, can produce. Some simple mathematical manipulation converts the TFP equation into a rate of change:

*Year-to-Year % Change in Total Factor Productivity = year-to-year % change in Value Added per Worker—(1-a) (year-to-year change in Capital per Employee).*

This equation has a powerful and simple explanation:

- 1 percentage change in Value Added per Worker is 'labor productivity.'
- 2 (1-a) (percentage change in Capital per Employee) is the contribution of added capital investment per worker to the change in labor productivity.

In the Table below, we summarize the TFP computation results for SW Co.:

Table 1: SW Co. TFP Computation

	1999	2000	2001	H1 2002	Percentage change 2000/1999	Percentage change 2001/2000	Percentage change H1 2002/2001
Labour Productivity (tons/line-hour)	N/A	N/A	N/A	N/A	2.16%	6.9%	0%
Capital per employee	\$29.6	\$29.9	\$32.2	\$34.6	1.11%	7.75%	5.64%
Percentage change in TFP	N/A	N/A	N/A	N/A	1.7%	3.2%	-2.25%

Notes:

- 1 Economic value added (EVA) = NOPAT (net operating profit after tax) minus the opportunity cost of capital. Here, we assume that shareholders can earn 20% on their investment in equally risky alternatives; hence  $EVA = NOPAT - (0.2) \text{ (capital)}$ . Economic value added (EVA) – return on shareholders' equity after deducting the opportunity cost of capital – has become a widely used measure of firm performance. The advantage of TFP measure is that it takes into account both labour and capital in measuring productivity, as well as, of course, sales and output.
- 2 % change in total factor productivity = % change in labour productivity minus (capital intensity coefficient) (% change in capital per worker).
- 3 Assumption: the capital intensity coefficient (1-a) is 0.4, typical for a capital-intensive firm.
- 4 One cannot aggregate the individual product line productivity, but can aggregate the percentage changes in product line productivity, to obtain SW Co.'s overall percentage change in labour productivity.

Total factor productivity growth was negative in H1 2002 in comparison with the year 2001 because labor productivity increase was zero. Confronted with declining productivity, SW Co. may need labor-saving investment to boost profitability. The steadily declining profit margins also connote that the return on invested capital has declined.

Indeed, SW Co.'s return on capital has declined constantly from 1995 to 2002. Thus, the pressure from labor costs in the context of a manufacturing recovery may need to spur further investment to boost efficiency. SW Co. also shares a common feature with many companies from different U.S. industries: the inability to mitigate the downside risks of their business.

### Ways to Mitigate Downside Risks

1. The build-up in operating leverage—defined as the depreciation charges divided by net operating income—that accompanied the 1995-2000 market boom means that U.S. companies would have to spread higher fixed costs of depreciation over a smaller-than-expected revenue base. Only by reducing capital stock in relation to output would it be brought back to or below desired norms. Firms should rely on the notion of long-term optimal capital-output ratio, given the cost of capital.

2. Over-investment crushed returns on invested capital, massively squeezing profit margins. The era of low-cost capital encouraged excess. Therefore, the return-on-capital should become the imperative benchmark for making capital-investment decisions.

3. Michael Porter has argued that many companies do not really understand what strategy is. They confuse it with operational effectiveness. Operational effectiveness consists of things such as better inventory management, zero defects manufacturing and business process reengineering. These can help to cut losses or increase profits but they suffer from an important weakness: they can be copied. Much of the management consulting business involves spreading examples of increased operational effectiveness from one company to another. An advantage gained in this way, while useful, is rarely sustainable. Other companies will hear about it and imitate it.

4. Companies should state clearly their rate of discounting the future. The reason is that the discount rate is the key. In other words, it makes a lot of difference whether the present "job-loss" recovery will last 2 or 5 years. As Professor Harold Linstone has emphasised, "the discount rate can have a startling effect on decisions." [27] Following the same line of thought, Esther Dyson warned that the greatest threat facing the economy is what she called the 'retreat to the present,' in other words, the shortening of time horizons and the inability or unwillingness to plan or invest for the future.

5. There are alternatives to forecasting. A decision maker can buy insurance (leaving the insurers to do the forecasting), hedge (bet on both heads and tails), or use 'just-in-time' systems (which push the forecasting problem off to the suppliers). [28] Hedging—or the use of derivatives—is also often used by businesses that are confronted with huge volatility in the markets in which they buy or sell products or services.

6. In financial markets, Richard Olsen shrewdly noticed that "there are groups whose trading decisions are based on different time horizons." [29] These trading horizons are of huge importance because they determine how individuals weight events. Olsen proposes an online global warning system that would generate a market 'weather map.' It would evaluate the probability of future market volatility and the expected direction of market moves. The problem with this proposal is not only that it requires a huge amount of data to be collected and analysed, but also because we do not see, so far, an institution willing to devote corresponding considerable resources to developing such a system.

7. Last but not least the speed of reaction of the decision makers is what matters most. By and large, forecasting methods are often performed poorly in organisations, sometimes because managers have too much confidence in their intuition. [30] Besides, humans have an innate tendency to ignore information that is inconsistent with their preconceptions about the world. [31] (For a psychologist's exploration of why this innate tendency is rational from the standpoint of human

evolution, please see [32]). Therefore, theory can lock in information that is important, and thus be dangerous to one's behaviour and wellbeing, not to mention one's personal safety. This is especially true when the world is changing rapidly, as it is today.

The 2001 recession has had truly unique characteristics. First and foremost, the speed with which economic events have unfolded since mid-2000 has taken everyone by surprise, including the U.S. Federal Reserve Board. The abruptness of the slowdown was startling. The age we live in is characterized by higher and higher speed. We used to think in terms of the positive impact of this fast pace on our life. But it left us totally unprepared for the downside risks. That is the reason why "there is good reason to challenge the relevance of relying on the past in predicting the future" [33] and to develop new methodologies, including an Early Warning Indicators approach such as the one we propose in this paper.

### **Applying the Early Warning System to SW Company**

The Early Warning System we have devised relies on two control parameters; the first parameter is ' $\Delta t$ ,' which represents the time span for getting information about the process; the second one is ' $\alpha_i$ ,' which represents a relative warning level that can inform the decision maker about the state of the process, a warning interval that points to an optimum decision making time span based on information availability (for more information about ' $\Delta t$ ' and ' $\alpha_i$ ,' please see our analytical model as presented in [5]). Thus, our Early Warning Indicators (EWI) system, suitable for companies such as SW Co., consists of an index, which is an average of 34 indicators of global, U.S., regional (i.e., Midwest), and company-specific activity.

The EWI index is constructed as a diffusion index. Diffusion indices have the properties of leading indicators and are convenient summary measures showing the prevailing direction of change and the scope of change. We have constructed EWI indices for orders, shipments, employment, supplier deliveries, inventories, prices and so on.

SW Co. has been particularly interested in having an EWI price index in order to anticipate price trends as well as to mitigate the volatility of steel prices (for readers unfamiliar with the steel industry it might be useful to know that the steel market is a spot/contract market which does not use futures and other derivatives to hedge against price exposure). Having said that, we need to mention that even if Early Warning Indicators can be presented as diffusion indexes, they are not diffusion indices in the proper sense of the word (as they are defined on the National Association of Purchasing Managers' website: [www.ism.org](http://www.ism.org)). The Early Warning System is a sensitivity structural matrix, which defines SW Co.'s response to a change in ' $\Delta t$ ' and ' $\alpha_i$ ,' which is to a change in the time of response and the decision speed of the business executives

running the company. In our example, a relatively small fluctuation of ' $\alpha_i$ ' and ' $\Delta t$ ' may lead to a dramatic change in the company's performance. Indeed, using again the SW Co. example, in the spring of 2000 the company bought too much steel, building huge inventory, in the anticipation of even higher steel prices and buoyant demand. In business parlance they double-ordered or, in layman's terms, they speculated. Both actions proved incorrect.

The price of hot-rolled sheet steel tumbled in the United States starting in August the same year, while demand reached a maximum in June 2000 after which it started to dry up, and has followed a long and painful downward trend ever since. How would EWI have changed the situation?

First, it would have alerted the management in real time (i.e., March 2000) that the company should slow down its purchasing of steel. In other words, EWI leads by three to four months. The company became aware of this fact only five months later, in August, *when it had full information, but when it was already too late*, in the sense that the carrying costs of a huge pile up in inventory led the company to its first negative net annual income in many years. Using the terminology we employed in our EWI model, in the case of SW Co., the value of ' $\alpha_i$ ,' i.e., of the warning interval was violated, since the decision maker was not informed about the projected state of steel demand in advance, *prior to* approaching the dangerous limit but only *after* it surpassed this limit.

Second, ' $\Delta t$ ,' the time span management needed for getting information about the supply/demand conditions, and which was set—correctly—by the company's management at one month, was exceeded by five months, that is, by 500%!

For the sake of simplicity however, we treat the EWI index as diffusion indices, so that we can build an EWI time series in order to benchmark the company's performance versus the performance of industry as a whole. But how efficient is it for a company to use an EWI index, instead of time series forecasting? Using the EWI index, SW Co. has diminished its material cost divergence from the industry's benchmark as published in the Purchasing Magazine [34] from \$11.36 per ton of steel in the 22 months preceding EWI implementation (May 1999–February 2001) to only \$8.45 per ton of steel in the 22 months after EWI implementation: March 2001 to December 2002.

That is a decrease in unit costs for the company by 25.6%! Given that on average SW Co. buys around 353 thousand tons of steel (hot-rolled sheet) yearly, the unit cost decrease (\$2.91) corresponded to annual material cost savings of \$1,027,230 in 2002 only. To gain perspective, it should be noted that the above-mentioned total cost savings amount represents 67.22% of SW Co.'s net operating income for the whole year 2002.

On the other hand, it might be interesting to note that during the 44 months—22 prior and another 22 after EWI implementation—hot-rolled steel prices have reached two peaks and two troughs, which means that the downward and upward

trends have cancelled each other out and, consequently, they have not influenced the results. EWI detects both upturns and downturns in a specific industry. If a dynamic regression model had been used for the same data series, the results would have been insignificant from a statistical point of view, in the sense that the cost savings would have been mediocre.

Similar cost savings have been obtained by implementing the EWI index in other U.S. industries: semiconductors, medical and communications equipment, non-durable consumer goods, etc.

## Conclusion

Why early warning systems like the one we presented in this paper have been ignored or downplayed by leading policy makers and their advisers in the 1990s is an interesting subject for research, but it is difficult to avoid the impression that herd effects are as frequent in the field of ideas and policy making as in the financial markets.[35] Once the herd is in full pursuit of the latest fashion it is deaf to any suggestion that it might be going in the wrong direction; but when it finally comes to a halt, the standard excuse for its behavior is that 'everyone else made the same mistake,' in which case everyone can be exonerated.

The stability of any socio-political-economic system ultimately rests on three crucial conditions: one, on whether it has legitimacy, i.e. whether the rules and procedures according to which authority is conferred and exercised can be justified and can be seen to be rooted in Adam Smith's 'moral sentiments of the population;' two, on whether the agreed rules, conventions of behavior, etc., maintain order in the system by encouraging acceptable behavior and penalizing the unacceptable; and three, on the welfare outcome, which recognizes that popular support for institutions and economic arrangements will not be sustained if the distribution of costs and benefits is considered by too many of the population to be unjust.[36]

The instability in the international financial system in the last decade, the aggressive pursuit of an ever-widening liberalization agenda, the market bubble and especially the 'infectious greed' that led to the present loss of confidence in the corporate world, all suggest that the global system may be rapidly moving dangerously closer to violating all three conditions. The intellectual excesses of market worship, laissez-faire and social Darwinism have had their glory days while notions of commonwealth, civic purpose and fairness have been—for too long—crowded out of the public debate.

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# Predicting Activist Behavior: An Analysis of the General Social Survey

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## Abstract

This analysis of the General Social Survey uses a multiple regression model with explanatory power of better than 14 percent to confirm that *perception of environmental threat* is the principal impetus of activism (defined by the author as at least three out of four of the following environmentally-oriented activities: protesting for a cause, signing a petition, belonging to an environmental group and contributing money). Two psychological factors of the potential activist suggested by previous research—empowerment and dissatisfaction with family life—also contribute to a regression model explaining activist behavior. This analysis corroborates earlier findings that the typical American environmental activist is more likely to be college-educated, female, between the ages of 29 and 45, the parent of one or two (but not more) children and living in a household with middle class or greater income. However the analysis does not confirm that there is a *modal* activist. Furthermore, unpacking dimensions of environmental threat does not substantively or significantly add to the model's explanatory power.

## Introduction

Currently, no universally embraced theory explains how attitudes are translated into activist responses or why one individual with avowed concern about an issue acts, while another expressing the same opinion does not.

Klandermans (1986) summarizes three basic explanations of ostensibly altruistic, public or activist response to situations: individuals may join a protest or response because of psychological factors, or after weighing perceived costs and benefits of participation (Olson 1965; Mayer 1989, Ostrum 1997) or because of relational and intergroup dynamics (Bourdieu 1973; Laumann and Pappi 1976; Blau 1977; Rytina and Morgan 1982; Hinkle, Fox-Cardamone, Lee, Haseleu, Brown and Irwin 1996).

The question remains. What initial set of conditions and stimuli motivates individuals to act publicly, rather than merely hold an opinion privately? Reicher (1982) and Parker (1997) argue that greater understanding of individual psychological processes in collective action can help sociologists approach other key problems of social theory, though this is disputed by others (McPhail and De Gruyter 1991).

Emphasizing this individual and psychological approach to the sociological question of collective action, this analysis has three purposes. First, it attempts to bring greater depth to a previous survey and to other investigations that identify perception of threat to health or life as the most salient and statistically significant stimulus producing an activist response. Second, it simultaneously tests the predictive value of two psychological factors: the empowerment of the potential activist and his or her dissatisfaction (with family life.) And third, though control variables (or demographic characteristics describing the individuals most likely to exhibit a certain behavior) are ordinarily of lesser theoretical interest, this investigation also explores the possibility of describing a modal activist—the member of society most likely to protest, become politically involved or even assume leadership when faced with a threat.

Although the relationship is hypothesized or assumed in interpretive and theoretical work, little empirical research has explored the relationship between activism and perception of threat to life or health and activist behavior. However, Seguin, Pelletier and Hunsley (1998) showed in a recent investigation that perception of threat was the most statistically significant explanation of activist behavior.

This analysis of the General Social Survey<sup>1</sup> uses a multiple regression model to take the work of Seguin et al. a step further by testing the combined explanatory power of five aspects of perception of threat to health or life. The regression analysis also includes two psychological factors: empowerment (used by Seguin et al.) and dissatisfaction with life suggested by Hoffer (1951), Aryee and Yaw (1997) and by Lee (1997) in another multiple regression analysis of predictive factors of activism.

Third, and not unimportantly, this analysis attempts to clarify the demographic portrait of the modal environmental activist.

The reason for this nested set of three research questions is the underlying hypothesis that testing each of these potential causal factors in isolation from the others is not sufficient to bring greater understanding to their combined effect.

The importance of the analysis is that it will add external validity and wider applicability to earlier analyses done on surveys conducted in very limited geographical regions. Second, the psychological factors tested in this analysis have either not been systematically tested before *or* have not been shown to be statistically significant in previous research. Third, the analysis can also greatly improve upon both the statistical explanatory power of earlier regression analyses as well as bring deeper understanding of the process by which a dissatisfied but empowered, or worried but relatively secure citizen makes the leap from private concern to public action.

### Literature Review

This review of the literature supports three aspects of this inquiry: perception of threat to life or health as an impetus toward activist behavior, two psychological predispositions and a demographic portrait of the modal activist. (This portrait will predominantly focus on environmental activists in the United States and Canada, but will also touch upon activism outside of North America and outside the realm of environmentalism.)

#### *Perception of Threat as the Principal Impetus for Activist Behavior*

Though few have tested it precisely, several authors have theorized or demonstrated the connection between perception of threat as a motivator and activist response. Speaking within the sub-discipline of sociology of risk, Clarke and Short (1993) note that the public responds differently to technological disasters than to natural disasters, specifically they assert that "threat perception is now more likely to galvanize public organization and complaint."

Although there was a relatively minor activist response to lead contamination, Tara McGee found in her combined qualitative and quantitative research that perception of health risks from the lead poisoning was a key motivator of what public response there was. (McGee, 1999).

Also linking perception of threat with activist response is the empirical report, "Of global concern: Results of the Health of the Planet Survey" (Riley, Gallup and Gallup 1993). The authors say, "In 19 countries, more than 70 percent believe [that there is a strong increase in reported health effects due to environmental degradation], which indicates that perception of environmental problems as a health threat—especially for the next generation—has become commonplace around the world."

Acknowledging the difficulty mentioned in the introduction in understanding how a set of attitudes is translated into action, Brent Steel (1996) also examines the problematic relationship between environmental attitudes, behavior and activism in "Environmental values and behavior: hypocrisy or consistency?" His paper empirically examines the effect of environmental attitudes on environmentally protective behaviors and political activism to attain environmental goals. Using data gathered from a 1992 national survey, he empirically explores the link between attitudes and self-reported behavior. While not explicitly mentioning perception of threat, his findings suggest that attitude intensity correlates with self-reported environmental behavior and political activism in environmental issues. An argument can be constructed that perception of threat is at the more intense end of the spectrum of environmental or other concern.

The finding of a sense of threat as a key motivator for citizen action is reinforced in qualitative research. In "Anthropological engagements with environmentalism," Brosius, Baviskar, Berglund, Dove et al. (June 1999) report that "Environmental threats motivate social action..."

Furthermore, both quantitative and interpretive research link perception of (predominantly environmental) threat to quality of life with activist responses (Abrahams 1999; Alm and Witt 1997).

### *Exemplary Empirical Test of Perception of Threat as a Motivator*

The major empirical test of perception of threat as a motivator to activist response was performed by Seguin, Pelletier and Hunsley, the Canadian authors of "Toward a model of environmental activism" (1998). They found that "perceived ecological risks played a central role in the determination of environmental activism."

To operationalize the concept of perception of threat, Sequin et al. constructed the independent variable, perception of health risk from 21 measures. Each represented a health threat related to environmental conditions (e.g., nuclear waste, fish caught in the St. Lawrence River, outdoor air quality, bacteria in food). Participants answered each item on a 7-point Likert-type scale, ranging from 1 (almost no health risk) to 7 (high health risk). The survey was mailed out randomly to Canadian households. There was a 24.4 percent response rate, yielding a sample size (N) of 709: 71 activists and 638 non-activists.

The model of activism by Sequin et al. was statistically tested by means of recursive path analyses using multiple regression. All the regressions were conducted using an activism scale with six components. In the first multiple regression analysis, five factors (relative autonomy index, amount of information concerning health risks and health issues, perception of responsibility of different organizations to prevent health risks, perceived importance of problems in the environment, and *perception of health risks related to environmental conditions*) were entered to identify which would best explain activist behaviors. The only factor in analysis with 709 cases that revealed statistically significant linkage with activist behaviors was perception of health risks. The authors conducted a second multiple regression similar to the first, but only with the significant variable. This analysis revealed a beta weight of .13. The  $R^2$  for the final model by Sequin et al. was 2 percent. In other words, the regression equation to express the variance in activist behaviors left 98 percent of the phenomenon of activism unexplained by the independent variables chosen by these researchers.

The hypothesis of this researcher is that the explanatory power of the Canadian model, although otherwise excellent, is so low because it was not sufficiently multivariate and that variables (specifically psychological factors and demographic characteristics) must be analyzed *together* to attain a higher  $R^2$ . On the completion of the project, Seguin et al. themselves also suggested that unpacking dimensions of perception of environmental threat may yield better results. It is this exemplar upon which this statistical inquiry is predominantly built.

### *Five Dimensions of Perception of Threat*

Five dimensions of threat encompass virtually every instance in the literature of perception of threat. They are 1) health risks or dangers to oneself and one's family, 2) concern about water pollution, 3) concern about air pollution, 4) concern about radiation and 5) general concern for nature.

Sequin et al. suggest that further studies should identify different components of health risks so as to improve sociological understanding of the relationship between citizens' perception of health risks and environmental activism. In their analysis, which dealt only with environmental activism, the Canadian authors found that the picture of a typical activist is one of an individual who "perceives as more important various possible problems in the environment such as the quality of the air, the level of pollution from automobiles and industries, and the degradation of animals' habitats." A review of the literature does not reveal inquiries, empirical or otherwise, that unpack and test these different components of perception of environmental threat. There is, however, literature on each of the five separate perceptions of threat as a stimulus for activism.

#### *Health Risks or Dangers to Oneself and One's Family*

Almost all of the qualitative research into incidents of environmental activism mention or assume the pollution problem as a threat to the activists' health and the health of their family members, particularly their children. For example, Abrahams (1999) found that the quality of life being protected by activist mothers was that of their children. Abrahams' finding supports the idea that threat to (oneself and) one's family may be the most motivating dimension of perception of threat.

#### *Concern about Water Pollution*

Contamination of the water was the threat to which residents at Love Canal responded, documented by Keller (1995), Levine (1982) and others. Lead contamination in South Wales, Australia was dispersed predominantly through the water table (McGee 1999) and therefore contamination of water is the concern in that research; and dispersement through water is the principle concern when citizens protest hazardous waste sites. (Bailey, Faupel, Holland, Warren 1989). In each of these studies cited, it was perception of threat because of contamination of the water that motivated an activist response.

### *Concern about Air Pollution*

Perception of threat from air pollution is less well documented and as a stimulus for activist response it is more difficult to isolate. A contaminant may pollute both the water and the air (in addition to soil and other media.) However, some limited literature links perception of threat from incinerator and industrial air pollution with activist response. (Asch and Seneca 1978, Hamilton 1993).

### *Concern about Radiation*

As with air pollution, there is cross-over in the way threats from radioactivity can be defined or categorized. Radioactivity may come from natural ores and other natural sources, nuclear bombs, materials used to make nuclear bombs and nuclear waste. The nature of activist efforts toward nuclear disarmament are not addressed here because their inclusion would necessitate an overview of the entire realm of peace activism. The principal activist response to a perceived threat from radioactivity (and subsequent academic examination of that response) has come as a result of hazards incumbent with nuclear energy and actual nuclear accidents. Threats to a sustainable lifestyle because of dependence on an energy source deemed risky motivated the activism reported by Geggie and Fairholm (1998), whereas straightforward risks to health from nuclear waste have motivated responses studies by other researchers (Mehta 1997.) And there has been research on the activist response to the nuclear accidents at Three Mile Island in 1979 and at the Chernobyl reactor in 1986. (Opp 1988; Merchant 1992; Walsh and Warland 1993; Dawson 1996).

Although his primary methodology was to conduct a multiple regression analysis of a random-sample survey of 626 household heads of Allegany County in upstate New York, Kowalewski (1995) also found that the "bump the dump" movement arising in 1988 to protest a proposed low-level nuclear waste (LLNW) facility split into two organizations, motivated by two kinds of threat: a moderate Concerned Citizens of Allegany County (concerned about threats to property values), and a more militant Allegany County Nonviolent Action Group which threatened civil disobedience (concerned about health and broader environmental protection).

There is also literature (Staub 1993) on perception of threat to lifestyle or property value as a motivator to racist or violent response, but this is a complex and problematic manifestation, may not even be activism as understood elsewhere and will not be treated here.

### *General Concern for Nature*

As for general concern for the environment, individuals do worry about beings other than themselves and their immediate kith and kin, although making the connection between this concern and activist response has been difficult. Survey respondents express concern about habitat destruction (Kellert 1979; Ingalsbee 1996), cruelty to animals (Kellert 1981; Eagles and Muffit 1990; Herzog, 1993; Peek, Dunham and Dietz 1997) and siting of toxic disposal facilities in poor and minority neighborhoods (Alston 1991; Austin and Schill 1991; Bailey and Faupel 1993) even when they themselves do not live in those neighborhoods. The link between this concern and activist response has been predominantly explored in a qualitative and normative realm, rather than researched quantitatively.

### *Empowerment and Dissatisfaction as Psychological Predispositions for Activist Behavior*

Empowerment and dissatisfaction, two major independent variables used in this analysis, can be found in the existing literature. Empowerment is conceptually similar to Seguin et al.'s relative autonomy index (RAI). Speer (1995), Herring (1999) and other authors also cite empowerment as a psychological attribute present with or preceding activist behavior. The idea that empowerment precedes and contributes to activist response is also consistent with resource mobilization theory (McVeigh 1995).

Conceptualizing it in several ways, authors have also cited dissatisfaction with life in general, dissatisfaction with personal life and relationships and dissatisfaction with other conditions of life as a factor preceding or stimulating activist behavior or participation in mass movements. Hoffer (1951) discusses dissatisfaction with personal life and relationship as a factor in mass movement participation. Dissatisfaction is related to the variable of cynicism used by Aie-Lee Rie in "Exploration of the sources of student activism: The case of South Korea." (1997) And Lee also uses satisfaction with college life as an independent variable, her analysis showing that higher dissatisfaction led to greater activism. Both Klanderman (1986) and (Aryee and Yaw, 1997) cite dissatisfaction (with work conditions) as a factor for joining a union.

### *Demographic Portrait of Activists*

The eight demographic variables reviewed here in terms of their connection to environmental activism are: education, sex, age, race, having children, middle class status, labor force status and community type. These variables are often analyzed in combination, with overlapping theoretical and structural explanations of why they may influence the likelihood of activism.

### *Environmental Concern in Younger People and More Educated People*

In a review of the literature on environmental concern, Van Liere and Dunlap (1980) and Jones and Dunlap (1992) tried to better define the relationship between environmental concern and various social and demographic variables such as age, sex, income, education, occupational prestige, place of residence, and political ideology. These researchers found environmental concern to occur in younger people and more educated people. Clearly defined political ideology also made environmental concern more likely. They found environmental concern to be inconsistently or weakly associated with income, occupational prestige, urban residency, and sex.

Current literature offers an inconsistent picture of the demographic characteristics of activists. Nonetheless, many researchers continue to operate under the assumption voiced by McCarthy and Zald (1973) that "the grassroots rise up after middle class citizens, in particular young, educated, liberal, urban professionals, apply their ideological and organizational skills to popular mobilization."

### *The Effect of Youth*

Kingsley Davis (1940) suggests that younger generations are imperfectly socialized because there is a gap between the memories and values they have learned from older generations and the reality that they perceive around them. And Schuman and Scott (1979, 1989) found that when people were asked which historical events had the greatest impact on their lives they most often mentioned events that occurred during young adulthood. Performing regression analysis on "Longitudinal study of three generations" (Bengtson & Roberts, 1991), Dunham (1998) tested the intergenerational theories Mannheim articulated in his essay of 1928, "The problem of generations." She found not that youth, per se, was a stimulus to peace activism but that "The greater the identification with the younger generation, the greater the likelihood of participating in demonstrations for peace." She found that those who attend college are more likely to participate in demonstrations for peace. Dunham also found that those who are married are less likely to participate in peace activism. Marriage, which comes with age and maturity, can reduce participation in activism (Kasschau, Ransford & Bengtson, 1974; Dunham & Bengtson, 1992). By contrast, young people are available to participate in social movements (Braungart, 1984). But it is for this same reason, of structural availability that housewives may have led the toxics movements of the 1970s and 1980s. (Bantjes and Trussler 1999).

Williamson (1998) disagrees that activists are always likely to be younger, predicting that the cohort (so-called baby boomers) active in the 1960s and 1970s may become active again once the concerns of professional life are finished.

### *Middle Class Status*

The radicalized citizens in the study by Kowalewski (1995) were significantly more likely to be middle class, educated, and employed in nonmarket services. They resided closer to one of the three possible sites for the facility being protested. They were more likely to have voted in the last presidential election. And they were less communitarian-idealistic (more conservative.) He also tested age, being female, having dependents and home ownership but did not find that they had a statistically significant relationship to protest against the proposed Low Level Radioactive Waste (LLRW) disposal facility. The explanation that Kowalewski gives for activists to be better educated and have stable middle class incomes is that "popular discontent is articulated by a middle class vanguard, which has the intellectual, financial, and other resources to fuel the embers of dissatisfaction. This vanguard radicalizes the unenlightened and conservative mass sectors."

### *Race*

No multiple regression analysis was found that linked race with environmental activism and although there are accounts of protest against so-called environmental racism (Allen, Lester and Hill 1995; Alston 1991; Austin and Schill 1991; Bailey and Faupel 1993), researchers have asked but not yet satisfactorily answered why so few non-whites participate in the mainstream environmental movement. (Adams 1992).

### *Being Female*

Though they argue that women's activism is philosophically deeper, "translocal" and not simply because they are available as housewives and concerned about their children, Bantjes and Trussler (1999) articulate that "within anti-toxics movement publications and academic literature, the figure of the housewife activist has begun to assume almost archetypal dimensions." Similarly, the qualitative finding by Abrahams (1999) that activist mothers are motivated by a desire to protect their children supports the portrait of the American environmental activist as a (comparatively young) mother. In fact, it is the interpretive and theoretical link between the experiences of women and environmental activism that best supports the idea that there may be a statistically demonstrable link between being female and becoming involved as an activist. However, the postmodern theoretical context of existing feminist treatments has left little room for quantitative analyses of this connection. This may be because the constructivist perspective of postmodernism and feminism does not mesh well with the objectivist stance of statistical analysis.

The literature cited offers some validation of a portrait of the (predominantly environmental) activist as being educated, female and young and having middle class status. Having dependents, working and where one lives have been of interest to previous researchers, but there as yet is no clear quantitative evidence for the influence of these

variables, though it is reasonable to assert that environmental activists (in contrast to other types of activists) may be more likely to live in rural regions because such regions are the locale of hazardous waste dumps, low level radioactive waste sites, incinerators and other contaminating facilities, which may stimulate protest.

### Research Focus and Hypotheses

In the simplest sense, the main hypothesis for this research is that perception of threat to health can predict self-reported activist behavior.

The first hypothesis ( $H_1$ ) is that considering various aspects of perception of threat to health—breaking it into five dimensions of perception of threat—will increase the explanatory power of a multiple regression model. Specifically, the researcher predicts that  $R^2$  will be increased over the  $R^2$  in earlier multiple regression models by separating out and testing the predictive power of five aspects of perception of threat: 1) health risks or dangers to oneself and one's family, 2) concern about water pollution, 3) concern about air pollution, 4) concern about radiation and 5) general concern for nature. None of these categories of threat is new. All of them come from previous research as well as from a *prima facie* understanding of the kinds of environmental threats a person or family might face. The categorization was developed before investigating the limits of the data set, but happily, the GSS question supports this taxonomy. Other researchers have looked at these factors, but not in a systematic way, therefore, this taxonomy of threats is one of the original contributions in this analysis.

Another way of saying this is that previous researchers have failed to take into account the important motivating factor of selfishness, which, though it may have a negative connotation, may produce a real benefit to those affected by the changes brought about by the (potential) activist who feels threatened and acts. The first category of perception of threat to self and family is the closest to home. The middle three: perception of threat because of water or air pollution or radiation are less immediate if one perceives them as a threat to others, but not to oneself and the fifth category is the most abstract and least immediate. It may be, in some cases, merely an aesthetic concern.

As discussed in the literature review, previous authors, including Sequin et al., Lee and Hoffer have posited *dissatisfaction* as a factor preceding or stimulating activist behavior and Sequin et al. used a factor they called the autonomy index, which is similar to empowerment. The second hypothesis ( $H_2$ ) is that the addition of two psychological characteristics of the potential activist, empowerment and dissatisfaction with family life will similarly increase the explanatory power of a multiple regression model. It is hypothesized that activists are more likely to report general dissatisfaction with life, but that being sufficiently empowered will also make respondents more likely to be activists. These two psychological factors have been chosen to be tested because they may be the two predispositions best generalized to other types of activism and because they are most consistently supported in the literature.

The third hypothesis ( $H_3$ ) is that the following control variables will also contribute to the multiple regression model: education, sex, age, race, number of children, household income, labor force status and community type.

Furthermore, it is hypothesized that activists will be better educated, younger, white, more likely to have children, middle class and will have a household income which allows the wife/mother to keep house as her primary occupation. One theoretical explanation for this is that housewives are more likely to be structurally available for activism (Bantjes and Trussler 1999). And it is hypothesized that the activists will be more likely to come from rural communities because waste disposal facilities and other sources of pollution are more likely to be located in rural or exurban areas. This is based on the finding by Kowalewski (1995) that residents living closer to a LLRW disposal site were more likely to have an activist response.

There is a fourth assumption implied along with these three that may not be able to be empirically tested, but it is nonetheless important. It may be there is a whole effect of perception of threat, psychological predispositions and demographic characteristics (with all of their implied cultural dimensions) that may be greater in combination than the sum of the parts. The literature does show that researchers have tried to measure mere positive attitudes toward the environment and these alone are very weak in their ability to predict activist behavior. It may be that a complex and subtle chemistry of life situation, psychological stance, combined with the triggering effect of perception of threat are what propel a citizen into action, taking him or her beyond merely expressing concern for the environment in a survey.

Another original contribution of this analysis of environmental activism is taking into account a more complex set of causal factors: the demographic, the psychological predispositions and the perception of threat to life and health. In light of the existing literature on the explanatory power of threat for activist behavior, an important undertaking is to break out threat into several dimensions and test their value in a multiple regression model. It is hoped that this will yield a higher explanatory power than the  $R^2$  of 2% attained by Sequin et al. Furthermore, it will be valuable to test empowerment and dissatisfaction and previously identified demographic characteristics in the same multiple regression model.

### *The Data Set*

The data set used for this analysis is the General Social Survey (GSS), an annual, omnibus, personal interview survey of U.S. households conducted by the National Opinion Research Center (NORC) of the University of Michigan, respected for the highest survey standards in design, sampling, interviewing, processing, and documentation. The GSS has an overall response rate of approximately 80 percent. Non-response in the GSS can occur at several points in the survey. There are two stages of information

collection: at the household level and at the individual level. Non-response at the household level averages 6 percent. Non-response also occurs at the level of individual questions. For most questions, the response rate is high and, in tables, the non-responses generally appear under the heading "not stated". This stands in contrast to the survey implemented by Seguin et al.

Although the operationalization of the various dimensions of perception of environmental threat in the GSS is satisfactory, its limitation is that these questions were only asked in a special module in 1993 and 1994, so although the GSS has questions asked in those two years which could replicate the other factors used by Seguin et al. and Kowalewski, those factors could not be tested in this multiple regression analysis.

### Measurement and Methods

#### *Dependent Variable*

The dependent variable in this analysis is activist behavior. Seguin et al. upon whose work this analysis is based, operationalized activism with six self-reported behaviors considered to be generally representative of activists' behaviors. These behaviors are (a) participating in events organized by ecological groups, (b) circulating a petition demanding an improvement of government policies regarding the environment, (c) participating in protests against current environmental conditions, (d) helping to financially support an ecological group, (e) voting for a government proposing environmentally conscious policies, and (f) writing letters to companies that manufacture harmful products.

For this analysis, activism was operationalized by constructing an index of four comparable activist behaviors. The four questions measured participation in demonstrations, environmental group membership, petition-signing and financial contribution to environmental groups. Though this operationalization was limited by the questions asked in the GSS (notably missing is communication with other citizens, to officials and to the press these components) this is a satisfactory match. Some authors do include criteria at the extreme ends of the continuum; vandalism and violence (Lee 1997); others include symbolic protest, but the four components of the index are a moderate representation of the general understanding of activism.

The exact wording of the four component questions is as follows:

I1. In the last five years, have you taken part in a protest or demonstration about an environmental issue? Y=1, N=2 dichotomous response plus DK=8, no answer=9 and not app.=BK.

I2. Are you a member of any group whose main aim is to preserve or protect the environment? Y=1, N=2 dichotomous response plus DK=8, no answer=9 and not app.=BK.

I3. In the last five years, have you signed a petition about an environmental issue? Y=1, N=2 dichotomous response plus DK=8, no answer=9 and not app.=BK.

I4. In the last five years, have you given money to an environmental group? Y=1, N=2 dichotomous response plus DK=8, no answer=9 and not app.=BK.

### *Constructing the Index of the Dependent Variable*

Constructing an index of a single dependent variable was achieved by adding the values for the four responses to the questions. As previously mentioned, all four responses are dichotomous. Missing responses for the other three components of the index were dealt with by assigning them a value of 2, so that a non-response is essentially collapsed into a negative response. Therefore, if the response is missing, the assigned value adds nothing to the positive activist status of the respondent, but the overall case is still usable in the analysis.

TABLE 1A. UNIVARIATE ANALYSIS OF DEPENDENT VARIABLE AND TYPES OF PERCEPTION OF THREAT

	N	MEAN	STANDARD DEVIATION	RESPONSE RATE
<b>INDEX OF ACTIVIST BEHAVIOR</b>	2719	7.1261	.9226	*
PROTESTED FOR ENVIRONMENTAL ISSUE	2719	1.97	.17	*
SIGN PETITION ON ENVIRONMENTAL ISSUE	2807	1.98	.15	*
MEMBER OF ENVIRONMENTAL GROUP	2879	1.99	.01	*
GIVE MONEY TO ENVIRONMENTAL GROUP	2724	1.96	.19	*
<b>FIVE TYPES OF PERCEPTION OF THREAT</b>				*
<b>PERCEPTION OF THREAT TO SELF AND FAMIL</b>				*
WATER POLLUTION DANGER TO MY FAMILY	2813	2.33	.96	*
PESTICIDES DANGER TO MY FAMILY	2787	2.67	.93	*
ALL PESTICIDES CAUSE CANCER	2632	2.71	.82	*
CAR POLLUTION DANGER TO MY FAMILY	2709	2.65	.92	*
INDUST AIR POLLUTION DANGER TO MY FAMILY	2789	2.38	.93	*
CAR POLLUTION WILL INCREASE IN NEXT 10 YRS	2651	2.65	1.00	*
ALL MAN-MADE CHEMS CAUSE CANCER	2591	2.53	.86	*
NUKE POWER DANGER TO MY FAMILY	2641	2.68	1.10	*
<b>PERCEPTION OF THREAT FROM WATER POLLUTION</b>				*
WATER POLLUTION DANGER TO ENVIR	2809	2.05	.92	*
PESTICIDES DANGER TO ENVIR	2798	2.62	.89	*
<b>PERCEPTION OF THREAT FROM AIR POLLUTION</b>				*
INDUST AIR POLLUTION DANGER TO ENVIR	2803	2.20	.88	*
CAR POLLUTION DANGER TO ENVIR	2715	2.43	.89	*
CARS NOT IMP CAUSE OF AIR POLLUTION	2714	3.20	.92	*
<b>PERCEPTION OF THREAT FROM RADIATION</b>				*
NUKE WASTE DANGEROUS FOR THOUSANDS OF YRS	2667	1.75	.64	*
ALL WILL DIE IF EXPOSED TO RADIOACT	2672	2.97	.86	*
NUKE POWER DANGER TO ENVIRONMENT	2654	2.54	1.04	*
HUMANS MAKE ALL RADIOACTIVITY	2555	2.87	.96	*
<b>GENERAL CONCERN ABOUT THE ENVIRONMENT</b>				*
HUMANS ARE MAIN CAUSE OF PLANT & ANIMAL EXTINCTION	2674	2.31	.87	*
HUMANS CHANGE NATURE FOR THE WORSE	2718	3.17	1.06	*
PEOPLE WORRY TOO MUCH ABOUT ENVIR, TOO LITTLE ABOUT THE ECONOMY	2822	3.02	1.22	*
ALMOST EVERYTHING WE DO HARMS ENVIRONMENT	2798	2.81	1.03	*
PEOPLE WORRY TOO MUCH ABOUT PROGRESS HARMING THE ENVIRONMENT	2797	3.17	1.09	*
NATURE WOULD BE AT PEACE IF HUMANS LEFT IT ALONE	2813	2.74	1.03	*

\*Response rate cannot be calculated because these questions were only asked in 1993 and 1994.

TABLE 1B. UNIVARIATE ANALYSIS OF DEMOGRAPHIC VARIABLES

	N	MEAN	STANDARD DEVIATION	RESPONSE RATE
FAMILY LIFE	24070	2.10	1.36	68%
FRIENDSHIPS	24128	2.24	1.24	68%
IT'S TOO DIFFICULT FOR SOMEONE LIKE ME TO DO ANYTHING ABOUT ENVIRONMENT	2783	3.36	1.06	*
HIGHEST YEAR OF SCHOOL COMPLETED	35178	12.36	3.20	99.7%
MALE	15467	1	0	100%
FEMALE	19817	1	0	100%
AGE OF RESPONDENT	35153	45.05	17.58	99.6%
WHITE	29604	1	0	100%
NONWHITE	5680	1	0	100%
NUMBER OF CHILDREN	35157	2.01	1.85	99.6%
TOTAL FAMILY INCOME	8551	14.96	5.29	76%
LABOR FORCE STATUS	35282	3.17	2.52	99.9%
TYPE OF COMMUNITY IN WHICH R LIVES	2874	2.65	1.18	92%

\*Response rate cannot be calculated because this question was only asked in 1993 and 1994.

Univariate analysis (frequencies) of the resulting constructed index ranges from a value of 4 to 8, with 4 or 5 indicating that the respondent is what will be called an activist for the purpose of this analysis. The average respondent has a mean activist score of 7.126. The distribution of the variable is highly skewed (-.910) because I am not measuring intelligence or height or some other characteristic with a normal distribution throughout the population, but rather a phenomenon that is relatively rare. Of 2719 valid cases, 25 self-report as activists who answered "yes" to all four questions and 134 self-report as having answered "yes" to three out of four questions. These are the cases marked in bold. Also, see Table 5 in the appendix.

So, approximately 6.7 percent of the population self-reports activist behaviors (in the environmental realm, which is the context of this analysis). I should note that the four questions operationalizing activism for this analysis ask if the respondent has *ever* participated in each of the four litmus activities. There I am making the assumption that citizens can be activists at some points in their lives and not at others. This analysis requires the possibly problematic assumption of a consistency of psychological stance in the respondent *who has ever been* an activist or reports that he or she *has ever* participated in activist activities, as reported here.

### Bivariate Analysis of the Index

The index of activist behavior has 2719 sample cases. This is the same for the index and its components because that is the way that nonresponses were handled. All correlations between the index and its components have two-tailed significance to a level of  $p = .003$  or better.

TABLE 2. shows Pearson Correlations for the activist index, its four component and the twelve independent variables used in the final multiple regression. The correlations among the four components of the index of activism and with the index itself

TABLE 2. CORRELATIONS FOR ACTIVIST INDEX, ITS 4 COMPONENTS &amp; 12 INDEPENDENT VARIABLES

	INDEX	PROTEST	PETITION	MEMBER	GIVE MONEY	PESTICIDES WATER POLLUTION	PESTICIDES ENDANGER FAMILY	PESTICIDES WATER POLLUTION	PESTICIDES ENDANGER ENVIRON.	PROGRESS	FAMILY LIFE	FRIENDSHIPS	TOO DIFFICULT	SEX	GE	RACE	EDUCATION	# OF CHILDREN
INDEX	1.000	.370	.741	.566	.737	.161	.104	.132	.132	-.266	.000	.106	-.271	-.036	.074	.075	-.261	.100
PROTEST	.2719	1.000	.176	.233	.058	.064	.070	.067	.067	-.096	-.088	-.049	-.091	.017	.063	.012	-.041	.067
PETITION	.2719	.2719	1.000	.355	.494	.056	.056	.085	.085	-.265	-.002	.018	-.258	-.002	.018	.015	-.098	.036
MEMBER	.2719	.2719	.2807	1.000	.301	.064	.064	.087	.089	-.101	-.001	.004	-.119	.001	.002	-.004	-.051	.019
GIVE MONEY	.2719	.2719	.2807	.2807	1.000	.083	.083	.081	.084	-.147	.004	.011	-.152	-.018	-.003	.001	-.080	.026
PESTICIDES ENDANGER FAMILY	.2593	.2602	.2878	.2787	.2798		1.000	.529	.837	-.102	-.045	-.009	-.015	-.149	.018	-.127	.057	-.017
WATER POLLUTION ENDANGERS FAMILY	.2615	.2615	.2813	.2813	.2979		.2715	1.000	.482	-.201	.038	.018	-.097	-.112	.125	-.041	-.039	.072
PESTICIDES ENDANGER ENVIRON.	.2602	.2593	.2719	.2719	.2807		.2813	.2724	1.000	-.109	-.041	-.018	-.009	-.141	-.004	-.092	.052	-.017
PROGRESS	.2610	.2610	.2797	.2979	.2797		.2678	.2704	.2688	1.000	-.017	-.012	.320	.035	-.164	-.112	.212	-.142
FAMILY LIFE	.937 (.988)	.941 (.007)	.2807 (.703)	.2807 (.888)	.2807 (.513)		.987 (.160)	.976 (.239)	.961 (.194)	.963 (.608)	1.000	.430	-.078	-.058	.034	.063	-.057	-.103
FRIENDSHIPS	.941	.941 (.136)	.2807*	.2807 (.563)	.24128 (.090)		.980 (.787)	.980 (.581)	.983 (.563)	.2675 (.698)	.24039	1.000	-.107	-.059	-.031	.129	-.094	.035
TOO DIFFICULT	.2593	.2593	.2807	-.119	-.152		.2660 (.448)	.2692	.2671 (.649)	.2675	.958 (.016)	.961	1.000	-.023	-.170	-.123	.329	-.097
SEX	.2719 (.063)	.2719 (.388)	.2807 (.666)	.2807 (.797)	.35284		.2787	.2813	.2798	.2797*	.24070	.24128	.2783 (.227)	1.000	.042	.028	-.050	.079
GE	.2713	.2713	.2807	.2807 (.706)	.2807 (.541)		.2782 (.340)	.2807	.2793 (.815)	.2792	.23973	.24030	.2778	.35153	1.000	-.072	-.283	.342
RACE	.2719	.2719 (.544)	.2807 (.006)	.2807 (.509)	.2807 (.844)		.2787	.2813*	.2798	.2797	.24070	.24128	.2779	.35284	.35153	1.000	-.091	.056
EDUCATION	.2715	.2715*	.2807	.2807	.2807		.2783*	.2810*	.2795	.2794	.24001	.24059		.35178	.35061	.35178	1.000	-.255
# OF CHILDREN	.2713	.2713	.2807	.2807	.2807		.2781 (.373)	.2807	.2792 (.360)	.2792	.23997	.24055	.2777	.35157	.35035	.35157	.35066	1.000

CORRELATIONS ARE SIGNIFICANT AT BETTER THAN P = .01 UNLESS NOTED

\*SIGNIFICANT AT P=.05 OR BETTER

STATISTICALLY INSIGNIFICANT CORRELATIONS IN PARENTHESES

reveal that the components are well-chosen, but interestingly some of the components do not have high correlations with one another, though they have correlations of .370, .566, .737 and .741 with the overall index. This indicates that activist behavior is a multi-dimensional phenomenon, which necessitates the construction of an index to be measured. For example, the self-reported characteristic of having protested for an environmental issue has a correlation of only .058 with that of having given money to an environmental group. In response to this observation, the researcher might argue that the young, perhaps not particularly wealthy, citizen may spend her time on a cause, but not have money to contribute. Conversely, others may make contributions without publicly protesting or being otherwise active in a cause.

Because I have constructed (and tested) a relatively continuous dependent variable, I can then proceed with Ordinary Least Squares (OLS) regression analysis.

### *Independent Variables: Five Types of Perceptions of Threat*

The analysis has a complex set of independent variables. They fall into three categories. The first category encompasses the variables that operationalize five types of perception of threat. The first kind of threat is health risks or dangers to oneself and one's family. Eight questions asked in the GSS in a special environmental module in 1993 and 1994 measured this kind of threat:

P1.1. Do you think that pollution of America's rivers, lakes and streams is ... 5-point Likert with 1=extremely dangerous for *you and your family* plus "can't choose," "no answer" and "not applicable," equaling 8, 9 and BK respectively.

P1.2. In general, do you think that pesticides and chemicals used in farming are... 5-point Likert with 1=extremely dangerous for you and your family plus "can't choose," "no answer" and "not applicable," equaling 8, 9 and BK respectively.

P1.3. All pesticides used on food crops cause cancer in humans. 4-point Likert with highest agreement = 1 plus "can't choose," "no answer" and "not applicable," equaling 8, 9 and BK respectively.

P1.4. Do you think that air pollution caused by cars is ... 1=extremely dangerous for your family; 2=very dangerous for your family; 3=somewhat dangerous for your family; 4=not very dangerous for your family; 5=not dangerous at all for your family; 8=can't choose; 9=no answer and BK=not applicable.

P1.5. In general, do you think that air pollution caused by industry ... 5-point Likert with 1=extremely dangerous for your family plus "can't choose," "no answer" and "not applicable," equaling 8, 9 and BK respectively.

P1.6. Within the next ten years, how likely do you think it is that there will be a large increase in ill-health in America's cities as a result of air pollution caused by cars? 5-point Likert with 1=extremely dangerous plus can't choose=8, no answer=9 and not applicable =BK.

P1.7. All man-made chemicals can cause cancer if you eat enough of them. 4-point Likert with highest agreement = 1 plus "can't choose," "no answer" and "not applicable," equaling 8, 9 and BK respectively.

P1.8. In general, do you think that nuclear power stations are ... 5-point Likert with 1=extremely dangerous for your family plus "can't choose," "no answer" and "not applicable," equaling 8, 9 and BK respectively.

The second type of perception of threat that it is possible to operationalize using the questions in the GSS is general concern about water pollution. Two questions measured this type of threat:

P2.1. Do you think that pollution of America's rivers, lakes and streams is ... 5-point Likert with 1=extremely dangerous for the environment plus "can't choose," "no answer" and "not applicable," equaling 8, 9 and BK respectively.

P2.2. In general, do you think that pesticides and chemicals used in farming are...5-point Likert with 1=extremely dangerous for the environment ... plus "can't choose," "no answer" and "not applicable," equaling 8, 9 and BK respectively.

The third type of perception of threat is general concern about air pollution. Three questions measured this type of threat:

P3.1. In general, do you think that air pollution caused by industry is ... 5-point Likert with 1=extremely dangerous for the environment plus "can't choose," "no answer" and "not applicable," equaling 8, 9 and BK respectively.

P3.2. In general, do you think that air pollution by cars is: 1. extremely dangerous for the environment 2. Very dangerous 3. Somewhat dangerous 4. Not very dangerous 5. Not dangerous at all plus can't choose = 8, no answer = 9 and not applicable = BK.

P3.3. Cars are not really an important cause of air pollution in America. 4-point Likert with highest agreement = 1 plus "can't choose," "no answer" and "not applicable," equaling 8, 9 and BK respectively.

The fourth kind of perception of threat is from radiation. Four questions measured this type of threat:

P4.1. Some radioactive waste from nuclear power plants will stay dangerous for thousands of years. 4-point Likert with highest agreement = 1 plus "can't choose," "no answer" and "not applicable," equaling 8, 9 and BK respectively.

P4.2. If someone is exposed to any amount of radioactivity they are certain to die as a result. 4-point Likert with highest agreement = 1 plus "can't choose," "no answer" and "not applicable," equaling 8, 9 and BK respectively.

P4.3. In general, do you think that nuclear power stations are ... 5-point Likert with 1=extremely dangerous for the environment plus "can't choose," "no answer" and "not applicable," equaling 8, 9 and BK respectively.

P4.4. All radioactivity is made by humans. 4-point Likert with highest agreement = 1 plus "can't choose," "no answer" and "not applicable," equaling 8, 9 and BK respectively.

The fifth and final type of perceived threat is general concern for nature. Six questions measured this type of concern.

P5.1. Human beings are the main cause of plant and animal species dying out. 4-point Likert with highest agreement = 1 plus "can't choose," "no answer" and "not applicable," equaling 8, 9 and BK respectively.

P5.2. Any change humans cause in nature—no matter how scientific—is likely to make things worse. 1=strongly agree; 2=agree; 3=neither agree nor disagree; 4=disagree; 5=strongly disagree; 8=can't choose; 9=no answer and BK=not applicable.

P5.3. We worry too much about the future of the environment, and not enough about price and jobs today. 1=strongly agree; 2=agree; 3=neither agree nor disagree; 4=disagree; 5=strongly disagree; 8=can't choose; 9=no answer and BK=not applicable.

P5.4. Almost everything we do in modern life harms the environment. 1=strongly agree; 2=agree; 3=neither agree nor disagree; 4=disagree; 5=strongly disagree; 8=can't choose; 9=no answer and BK=not applicable.

P5.5. People worry too much about human progress harming the environment. 1=strongly agree; 2=agree; 3=neither agree nor disagree; 4=disagree; 5=strongly disagree; 8=can't choose; 9=no answer and BK=not applicable.

P5.6. Nature would be at peace and harmony if only humans would leave it alone. 1=strongly agree; 2=agree; 3=neither agree nor disagree; 4=disagree; 5=strongly disagree; 8=can't choose; 9=no answer and BK=not applicable.

These variables are particularly valuable because some pairs of variables are identically worded with the only change being that the phrase "dangerous for *you and your family*" (*italics mine*) is replaced with "dangerous for the environment."

### *Independent Variables: Two Psychological Predispositions*

The next category of independent variable is psychological predispositions. Because the variables comprising the two dependent variables of activist behavior was only asked in 1993 and 1994, only empowerment and dissatisfaction with life could be tested as factors leading to attitudes about the environment and activist behavior, although there were related questions asked in other years. The psychological factor of empowerment was measured with the response to the statement:

D1. It is just too difficult for someone like me to do much about the environment. 1=strongly agree; 2=agree; 3=neither agree nor disagree; 4=disagree; 5=strongly disagree; 8=can't choose; 9=no answer and BK=not applicable.

The two questions used to test dissatisfaction refer to friendships and family life:

D2. Tell me the number that shows how much satisfaction you get from your family life. 1=a very great deal, 2=a great deal, 3=quite a bit, 4=a fair amount, 5=some, 6=a little, 7=none, 8=don't know, 9=no answer, BK=not applicable

D3. For each area of life I am going to name, tell me the number that shows how much satisfaction you get from that area: your friendships. 1=very great deal, 2=a great deal, 3=quite a bit, 4=a fair amount, 5=some, 6=a little, 7=none, 8=don't know, 9=no answer and BK=not applicable.

The operationalization of dissatisfaction in this analysis is slightly problematic because the meaning of dissatisfaction differs as used by various writers. When Hoffer (1951) posits that dissatisfaction is a characteristic of people who enter mass movements, he means that they consider their lives generally unfulfilled and they turn to the excitement and sense of purpose that collective action can offer. Conversely, when Lee (1997) writes that people experience cynicism and dissatisfaction, she implies that they see injustice and unethical social situations and are therefore motivated to protest against them. The questions in the GSS about satisfaction with friendship and family life have

the closest affinity to Hoffer's meaning of the term, and may even reflect the restlessness or need for a purpose that is implied in Lee's analysis. They do not encompass a sense of anxiety about environmental problems or outrage at injustice. When Kowalewski (1995) and other authors writing specifically about environmental activism refer to dissatisfaction they imply that it is selfish dissatisfaction. Something is specifically wrong in the activist's world and he or she is motivated to change it. The variation in this operationalization is one of the threats to validity in this analysis.

### *Independent Variables: Eight Demographic Characteristics*

The demographic variables used in the analysis are education, sex, age, race, number of children, household income in 1991, labor force status, community type.

### *Addressing the Issue of Nonresponses*

The first step in this analysis, which employs the software entitled Statistical Packages for the Social Sciences (SPSS), was to construct an index of the dependent variable. There are four questions in the GSS that measure activist behavior. They ask whether a respondent has participated in an environmental protest, whether he or she has signed a petition concerning an environmental issue, whether he or she has been a member of an environmental organization and whether he or she has contributed financially to an environmental group.

However, before constructing the index of the dependent variable, it was necessary to account for nonresponses in the four questions making up the index of activism. Nonetheless, for the two years that include the variables, there are, respectively, only 2 responses missing for 2719 the question was asked, 3 out of 2807, 64 out of 2879 and 2 out of 2724 for GRNDEMO, GRNSIGN, GRNGROUP and GRNMONEY. It seems that these are questions which people seem to understand and to which they seem to respond with relative willingness; there are sufficiently few missing responses to support the assumption that even if non-responses occurred in some systematic way, that there are too few missing responses to skew the data.

The response rates for the GSS are 82% in 1993 and 78% in 1994. The response rate for individual rotating questions is only given in the codebook as valid cases in the years asked versus the missing cases due to non-response/missing data combined with the missing data from all the years the questions was not asked, so that the question about pesticides being dangerous for the environment, for example, appears as: valid cases = 2798; missing cases = 32486. This does not allow accurate calculation of the actual response rate for that specific question. The number of valid cases for the variables used here ranges from about 2600 to almost 2900 responses.

It was necessary, however, to remove non-responses to a key question (and to simultaneously remove the cases not interviewed in 1993 and 1994). This was done by assigning the dependent index (INDEX\_B) to have a value of system missing if the response was missing for the questions about having participated in an environmental demonstration (GRNDEMO). The reasons for choosing this variable are 1) having participated in an environmental protest is a crucial behavioral determinant of activist status and 2) it is the component which had the smallest number of valid cases.

### Results

The first hypothesis ( $H_1$ ), that unpacking perception of threat to health into five dimensions of perception of threat would increase the explanatory power of a multiple regression model is only slightly supported in the in regression model.

The second hypothesis ( $H_2$ ), that the addition of two psychological characteristics of the potential activist, empowerment and dissatisfaction with family life would similarly increase the explanatory power of a multiple regression model was supported for both psychological dispositions.

The third hypothesis ( $H_3$ ), that education, sex, age, race, number of children, household income, labor force status and community type would paint a portrait of the modal activist was supported for some demographic characteristics, but not for others. Adding the control variables did contribute to the explanatory power ( $R_2$ ) of the final model.

TABLE 3. shows three models of activist behavior regressed on perceptions of threat, two types of life satisfaction and empowerment with demographic control variables: (education, sex, age, race and number of children) it is apparent that the variable with the single greatest influence on activist behavior in the final regression model (and in the other models) is education and, as such, merits further analysis.

I investigated this influence of education by dichotomizing the activist index into activists and non-activists and trichotomizing education into three levels: 1) having fewer than nine years of education 2) having some high school or a high school degree and 3) having some college or a four-year degree or better. The cross-tabulation showed that *not a single one* of the 159 respondents designated as activists in this analysis had fewer than nine years of school (and as cross-tabular analysis showed with the uncollapsed education variable, only nine had less than a high school education). As TABLE 4 shows, 77.4 percent had some college or better. (See appendix for Table 4. CROSS-TABULATION OF COLLAPSED EDUCATION VARIABLE BY COLLAPSED ACTIVISM INDEX).

TABLE 3. ACTIVIST BEHAVIOR REGRESSED ON PERCEPTIONS OF THREAT, LIFE SATISFACTION &amp; EMPOWERMENT; CONTROLLING FOR EDUCATION, SEX, AGE, RACE AND NUMBER OF CHILDREN

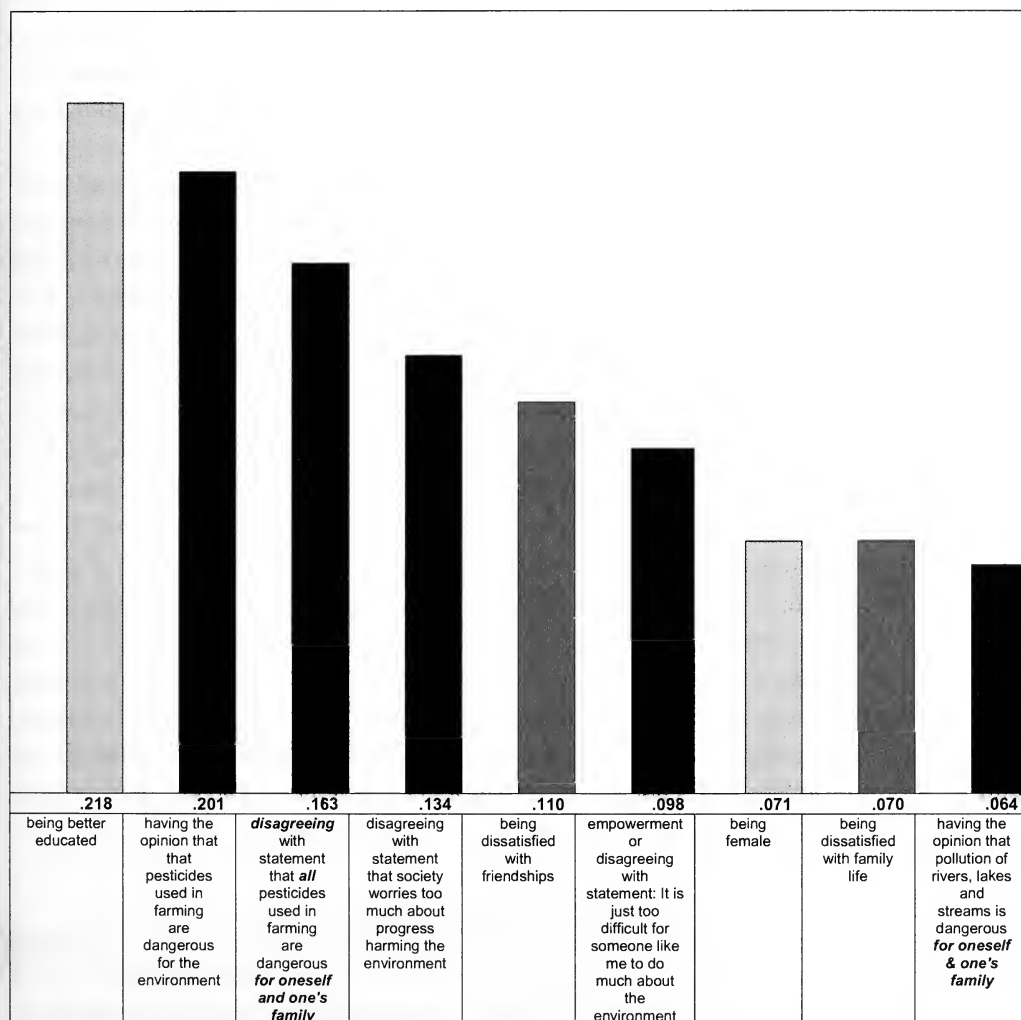
	model 1 demographic portrait		model 2 perceptions of threat, concern for environment and demographic characteristics		model 3 with perceptions of threat, concern for the environment, psychological factors and demographic characteristics	
	beta	p-value	beta	p-value	beta	p-value
<b>perceptions of threat</b>						
disagreement that pesticides used in farming are dangerous <i>for oneself and one's family</i>			-.052	<b>.150</b>	-.162	.006
opinion that pollution of rivers, lakes and streams is dangerous <i>for oneself &amp; one's family</i>			.078	.001	.059	<b>.130</b>
opinion that pesticides used in farming are dangerous for the environment			.132	.000	.203	.000
<b>general concern for the environment</b>						
disagreement with statement that society worries too much about progress harming the environment			-.192	.000	-.132	.000
<b>psychological characteristics</b>						
satisfaction with family life					-.069	.064
satisfaction with friendships					.107	.004
empowerment					-.093	.012
<b>control variables</b>						
education	-.249	.000	-.224	.000	-.218	.000
sex	-.056	.003	-.028	<b>.145</b>	-.071	.034
age	.006	.002	.047	.015	.027	<b>.433</b>
race	.059	<b>.765</b>	-.019	<b>.362</b>	.006	<b>.871</b>
number of children	.037	.076	.019	<b>.360</b>	.007	<b>.840</b>
R <sup>2</sup> <sub>adj</sub>		.074		13.7		14.2
number of cases (N)		(2709)		(2436)		(817)

Model three of the regression analysis, which combines demographic characteristics with perceptions of threat and concern for the environment uses four variables whose contribution is not statistically significant, but the dramatic value of this model is nonetheless that when the two clusters of variables (perception of threat and demographic characteristics) are combined the explanatory power of the model catapults up to 13.7 percent, though the two sets of demographic and perception of threat variables individually only explains less than one percent of the variance in activist behavior. This interaction says something important about considering perceptions of threat and concern for environment *along with* demographic characteristics

The fifth and final model uses nine variables to explain activist behavior. The final multiple regression model showed that opinion that pollution of rivers, lakes and streams is dangerous *for oneself & one's family* and the opinion that pesticides used in farming are dangerous for the environment did play an explanatory role in the phenomenon of activism. Disagreement that pesticides used in farming are dangerous for oneself and one's family was also a factor, as discussed above. And general concern for the environment was reflected in disagreement with the statement that society worries too much about progress

harming the environment. In order of their beta weights, the values of the nine statistically significant variables that explain activist behavior are: agreeing that pesticides used in farming are dangerous for the environment, disagreeing with statement that pesticides used in farming are dangerous for oneself and one's family, disagreeing with statement that society worries too much about progress harming the environment, being dissatisfied with friendships, empowerment or disagreeing with statement: It is just too difficult for someone like me to do much about the environment, being female, being dissatisfied with family life and having the opinion that pollution of rivers, lakes and streams is dangerous for oneself and one's family. Chart 1 is a bar chart of the beta weights of the nine variables in the final model. Although their beta weights are relatively small, the model does support the findings

CHART 1. BETA WEIGHTS FOR NINE INDEPENDENT VARIABLES EXPLAINING ACTIVIST BEHAVIOR



DEMOGRAPHIC FACTORS  
ATTITUDINAL FACTORS  
PSYCHOLOGICAL FACTORS

of earlier research that a dimension of dissatisfaction, dissatisfaction with family life, is an explanatory factor in environmental activism and this is in comparison with satisfaction with friendships, with which the activist expresses satisfaction.

The greatest disappointment of this research was that the high degree of explanatory power from breaking out dimensions of perception of environmental threat did not materialize. The GSS is adequate to operationalize activism, and (at least) five dimensions of perception of risk and the two psychological (as well as demographic variables) the eight variables measuring perception of health risks or dangers to oneself and one's family, the two measuring perception of threat from water pollution, the three measuring perception of threat from air pollution, the four measuring perception of threat from radiation and these six variables measuring a sense of general concern for the environment, but in combination with other theoretically important variables, only CHEMFAM, WATERFAM, CHEMGEN and GRNPROG ultimately made a significant contribution to a model explaining activist behavior and that inclusion showed *disagreement* that pesticides used in farming are dangerous for oneself and one's family was an explanatory factor for activism, not agreement.

Please see the chart of beta weights of independent variables. Disagreeing with statement that *all* pesticides used in farming are dangerous for oneself and one's family is included as a variable that is included in the final model. This is because the contribution of variables such this one—grntest5<sup>2</sup> and also scitest5<sup>3</sup>—which expressed a panicked or misinformed environmental worry, consistently had coefficients reflecting that activist respondents were *more* likely to disagree with these statements. (Please see the full text of some questions regarding perception of threat about radioactivity. These also have the potential to reflect misinformed environmental worry. Disagreeing with statements reflecting misinformed environmental worry is consistent with the finding that environmental activists are more likely to be well-educated as well as with the idea that environmental activists are not wildly fearful of all potential threats, but focussed and specific in their perception of danger to themselves and their families and to the environment in general. This discovery that respondents who reported a perception of threat to *some* environmental problems did not perceive threats in other realms led to the decision to retain in the final model a variable measuring *disagreement* that *all* pesticides used in farming are dangerous for oneself and one's family. The middle class and well-educated activist may also be aware of the danger to others or to the environment in general of pesticides used in farming, but does not feel that it specifically threatens his or her family.

### *Demographic Characteristics*

The regression analysis also tested (in various models with various combinations of measures of perception of threat) the explanatory power of the set of eight demographic variables suggested by the literature: education, sex, age, race, number of children,

income, work status and community type. The question of whether it is possible to describe, as the literature suggests, a typical North American environmental activist proceeded from there. Cross-tabular analysis shows that the activists responding in this data set were more likely to be well educated. Chart 1, the chart of beta weights, also shows that this was the most powerful predictive factor for activist behavior.

(See appendix for Table 4. Cross-tabulation of collapsed education variable by collapsed activism index).

The analysis shows that activists are most likely to be between the ages of 29 and 45 (in 1993 and 1994). The only other demographic variable that was substantive and significant in the final regression model was sex, showing that activists are more likely to be female. Age, however, was significant in models (1), 3 and 4 of the regression analysis and seem to show that the younger a respondent is, the more likely it is that he or she will become an environmental activist. This is misleading, however. The variables for both the age and the number of children (childs) (below) violate assumption four of Ordinary Least Squares regression, because they do not have a linear relationship with activist behavior. Furthermore the correlation between index\_b, the index of activist behavior and age is only .074 and the absolute value of the beta coefficient for activists' behavior and age in model 4 is only .027. Cross-tabular analysis is necessary to clarify the role of age in predicting or explaining activist behavior.

If I dichotomize index\_b, the index of activist behavior, I can clarify this non-linear relationship and see that more than half of the activists in the sample (54.4%) are between the ages of 29 and 45 and there is more than a 10 percent difference from the non-activists in the same age bracket. The next most likely activists are respondents older than 45 and the least likely is respondents between the ages of 18 and 28. It is this cohort of people born roughly between 1948 and 1964 who are shown to be the most active in this analysis.

Table 8. CROSSTABULATION OF COLLAPSED AGE VARIABLE BY COLLAPSED ACTIVISM INDEX (ACTIV2)

AGE		ACTIVISTS	NON-ACTIVISTS	Total
		1.00	2.00	
<b>AGED 18 TO 28</b>	Count	20	435	455
	% within ACTIV2	12.7%	17.0%	16.8%
<b>AGED 29 TO 45</b>	Count	86	1003	1089
	% within ACTIV2	<b>54.4%</b>	39.3%	40.1%
<b>OLDER THAN 45</b>	Count	52	1117	1169
	% within ACTIV2	32.9%	43.7%	43.1%
Total	Count	158	2555	2713
	% within ACTIV2	100.0%	100.0%	100.0%

Though it seems to indicate that activists are more likely to be white, the variable of race is significant in none of the five regression models. This probably due to the fact that there are only 12 non-white activists in the sample.

Table 9. CROSSTABULATION OF RACE OF RESPONDENT BY COLLAPSED ACTIVISM INDEX (ACTIV2)

			ACTIV2		Total
			1.00	2.00	
RACE OF RESPONDENT	WHITE	Count	147	2123	2270
		% within ACTIV2	92.5%	82.9%	83.5%
	BLACK	Count	8	315	323
		% within ACTIV2	5.0%	12.3%	11.9%
	OTHER	Count	4	122	126
		% within ACTIV2	2.5%	4.8%	4.6%
Total		Count	159	2560	2719
		% within ACTIV2	100.0%	100.0%	100.0%

According to cross-tabular analysis, the activists in this sample seemed more likely to be white. Like the variable of age, the number of children has a non-linear relationship with activist status. Unlike age, the number of children is not significant or elucidating in the final regression analysis. However, crosstabular analysis shows that people who have one or two children are the most likely to become environmental activists.

Table 10. CROSSTABULATION OF COLLAPSED VARIABLE FOR NUMBER OF CHILDREN (CHLD1\_2) BY RESPONDENT BY COLLAPSED ACTIVISM INDEX (ACTIV2)

		ACTIVISTS	NON-ACTIVISTS	Total
RESPONDENT HAS NO CHILDREN	Count	58	710	768
	% within ACTIV2	36.5%	27.8%	28.3%
ONE OR TWO CHILDREN	Count	79	1082	1161
	% within ACTIV2	49.7%	42.4%	42.8%
THREE OR MORE CHILDREN	Count	22	762	784
	% within ACTIV2	13.8%	29.8%	28.9%
Total	Count	159	2554	2713
	% within ACTIV2	100.0%	100.0%	100.0%

Activists in this sample seemed more likely to have a middle-class or upper middle class household income. There were 151 respondents with activist status who also answered the question about their total household income in 1991 (and 2330 non-activists answered for a combined N of 2481). Total household income in 1991 (income91) fell out of the regression models, but crosstabular analysis shows that respondents reporting middle class to upper middle class income were more likely to be activists. Nearly half or 46.4% of the 151 respondents had a total household income of \$50,000 or more (compared with only 24% of the non-activists in that income bracket). In fact, cross-tabulation with the uncollapsed income variable showed that fully 24.5% of the activists had incomes of \$75,000 or more, compared with less than 10% of the non-activists.

Table 11. CROSSTABULATION OF COLLAPSED VARIABLE TOTAL FAMILY INCOME IN 1991 (INCOME91) BY COLLAPSED ACTIVISM INDEX (ACTIV2)

		ACTIV2		Total
		activists	non-activists	
Less than \$1000 to 14,999	Count	16	564	580
	% within ACTIV2	10.6%	24.2%	
\$15,000 to 24,999	Count	18	434	452
	% within ACTIV2	11.9%	18.6%	
\$25,000 to 49,999	Count	47	772	819
	% within ACTIV2	31%	33%	
\$50,000 to \$75,000	Count	70	560	630
	% within ACTIV2	46.4%	24%	
Total		151	2330	2481

Activists in this sample seemed more likely to work fulltime or part-time (rather than keeping house). Surprisingly, although the typical environmental activist in this data set is white, suburban and middle class, she is not a housewife. Cross-tabular analysis shows that the activist as defined here is more likely to be working fulltime (or parttime) and is less likely to be keeping house. However, there is not a ten percent difference between any of the activists and non-activists and, as is the case for community type (below), collapsing the categories of work status may muddy what can be said about the influence of a particular labor force status on activist behavior.

Table 12. CROSSTABULATION OF LABOR FORCE STATUS (WRKSTAT) BY COLLAPSED ACTIVISM INDEX

		ACTIVISTS	NON-ACTIVISTS	total
WORKING FULLTIME	Count	97	1339	1436
	% within ACTIV2	<b>61.0%</b>	52.3%	52.8%
WORKING PARTTIME	Count	20	280	300
	% within ACTIV2	12.6%	10.9%	11.0%
TEMP NOT WORKING	Count	3	58	61
	% within ACTIV2	1.9%	2.3%	2.2%
UNEMPL, LAID OFF	Count	6	78	84
	% within ACTIV2	3.8%	3.0%	3.1%
RETIRED	Count	14	349	363
	% within ACTIV2	8.8%	13.6%	13.4%
SCHOOL	Count	4	74	78
	% within ACTIV2	2.5%	2.9%	2.9%
KEEPING HOUSE	Count	13	331	344
	% within ACTIV2	8.2%	<b>12.9%</b>	12.7%
OTHER	Count	2	51	53
	% within ACTIV2	1.3%	2.0%	1.9%
	Count	159	2560	2719
	% within ACTIV2	100.0%	100.0%	100.0%

The type of community was not a conclusive contributing factor. Although Kowalewski found activism to be more prevalent in rural areas, cross-tabular analysis of this data set did not find substantive trends for community type as a variable influencing activist behavior. A third of the activist respondents live in suburbs, but there is only an eight percent difference with the non-activists and not other clear trends. It might be possible to collapse two or more of these six community types, but then one gets into issues of combining community types that are not culturally similar.

Table 13. CROSSTABULATION OF COMMUNITY TYPE (COMTYPE) BY COLLAPSED ACTIVISM INDEX

TYPE OF COMMUNITY	ACTIVISTS	NON-ACTIVISTS	
BIG CITY	20.3% (31)	18.9% (477)	19.0% (508)
SUBURBS or OUTSKIRTS	<b>33.3% (51)</b>	25.2% (634)	25.6% (685)
SMALL TOWN	34.0% (52)	39.9% (1006)	39.6% (1058)
COUNTRY VILLAGE	2.0% (3)	4.3% (108)	4.2% (111)
(FARM or COUNTRY HOME	10.5% (16)	11.7% (295)	11.6% (311)
	100.0% (153)	100.0% (2520)	100.0% (2673)

### Discussion

At its core, this analysis aims for an individual explanation for why people expressing similar attitudes and living in similar environments respond differently. Which factors are the most important in stimulating action? Why does one person take action publicly when another does not? Such research into activism is critically important to the entire field of sociology (and its cousins, social psychology, management theory, political science, etc.) because it raises several questions that go to the heart of why individuals function in groups and in society the way they do. How can our understanding of agency and structural factors be integrated into a theory of behavior? What rules apply at the individual level? What rules apply in a theory of collective action at the micro, meso and macro levels?

The principal success of the analysis is that it uses a large sample size from a highly reliable and respected data set to corroborate the trigger effect of perception of threat in activist behavior and to greatly increase the explanatory power of a model including four dimensions of perception of environmental threat (or concern for the environment). It is also exciting to see a clearer and more specific test of the psychological factors dissatisfaction with family life, in contrast with satisfaction with friendships and in combination with empowerment. The principal shortcoming of the analysis is that more dimensions of perception of threat could not be included in the final model and that only education and age were significant in the final regression.

Relevant to the fourth assumption of the hypotheses section, this analysis depends on taking a complex set of causal factors together and in doing so, it pushes the limits of statistical analysis.

### *Flaws of the Analysis*

Notably missing from the index operationalizing activism is communication with other citizens, to officials and to the press. The GSS contains questions about having spoken publicly about issues as well as hypothetical questions about speaking publicly, but they were not asked in 1993 or 1994 (nor do they specifically deal with environmental issues). These four responses are adequate because they deal with behavior, not merely attitudes and they are simple measures of that behavior which respondents can readily report, therefore the researcher asserts that there is a strong internal validity.

Although the operationalization of activism and measurement of types of environmental concern possible with the GSS were satisfactory, some factors measured by other authors could not be included because the questions measuring activist behaviors were only asked in 1993 and 1994. Therefore questions to be used had to have been asked in those same years. Both Lee and Sequin et al. include readership of newspapers and other information sources and the question about reading the newspaper was not asked in 1993 or 1994.

Kowalewski and Sequin et al. also include voting as either a predictive factor or a component of activist behavior and having voted should be integrated with the factors examined here in future analyses.

### *Future Research*

Although the variables in the General Social Survey offered highly satisfactory internal validity, this analysis does suggest the need for a tailored survey with a better operationalization of the full and complex set of psychological factors which may be predispositions to activist behavior. Furthermore, although GSS is adequate to differentiate between activists and non-activists, it does not afford a sufficiently fine grain to differentiate among elite activists, citizen activists and ordinary citizens, three categories (Flacks 1970) in which the psychological characteristics may be markedly different.

Preliminary work for this analysis suggested that it may be fruitful to examine the explanatory factors analyzed here plus the characteristic of having voted in the 1992 election plus attitudes about trust or lack thereof toward the government in a combined model to predict or explain activist behavior versus mere positive attitudes toward the environment.

Third, people can hold certain beliefs, which, as sociologists we can attempt to operationalize and measure, but how do such beliefs lead to action? For example, what are the most salient attributes in explaining the emergence of activist behavior. Further research is suggested into the link between environmental attitudes and environmental activism. The insight into psychological predispositions for activism begun here may lead to a breakthrough in understanding how external circumstances plus attitudes plus demographic characteristics plus psychological characteristics lead to concrete actions in the social sphere.

Though this research seems to describe an average or typical activist, there seems to be no modal activist. Similarly, the influence of various demographic characteristics in the activists: being educated, female, more likely to be between the ages of 29 and 45, white, more likely to have one or two children, have a middle class or better household income, work outside the home and live in a small town or in the suburbs is supported in crosstabular analysis, but the fact that these variables are not significant in regression analysis shows that activists do not belong to one homogeneous group, but slightly overlapping groups that comprise activists. In addition, further analysis of this data set may disprove the idea of a "unified field theory" of activism. People may, in fact, become activists for different reasons and there are different though overlapping demographic groups and groups with psychological dispositions or perceptions who become activists. For example, the activist who participates publicly and spends a significant amount of time may not be the same as the one who contributes money to support environmental organizations, a trend known as "checkbook activism." (Switzer 1996)

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### Notes

1. The General Social Survey (GSS) is an annual, omnibus, personal interview survey of U.S. households conducted by the National Opinion Research Center (NORC) of the University of Michigan.
2. All pesticides used on food crops cause cancer in humans. 4-point Likert with highest agreement = 1 plus "can't choose," "no answer" and "not applicable," equaling 8, 9 and BK respectively.
3. All man-made chemicals can cause cancer if you eat enough of them. 4-point Likert with highest agreement = 1 plus "can't choose," "no answer" and "not applicable," equaling 8, 9 and BK respectively.

**Appendices:**

See the body of the text for:

TABLE 1A. UNIVARIATE ANALYSIS OF DEPENDENT VARIABLE AND TYPES OF PERCEPTION OF THREAT

TABLE 1B. UNIVARIATE ANALYSIS OF DEMOGRAPHIC VARIABLES

TABLE 2. CORRELATIONS FOR ACTIVIST INDEX, ITS 4 COMPONENTS & 12 INDEPENDENT VARIABLES

TABLE 3. ACTIVIST BEHAVIOR REGRESSED ON PERCEPTIONS OF THREAT, LIFE SATISFACTION & EMPOWERMENT; CONTROLLING FOR SEX & EDUCATION

Table 4. CROSSTABULATION OF COLLAPSED EDUCATION VARIABLE BY COLLAPSED ACTIVISM INDEX (ACTIV2)

		ACTIVISTS	NON-ACTIVISTS	Total
FEWER THAN NINE YEARS OF EDUCATION	Count		183	183
	% within ACTIV2		7.2%	6.7%
SOME HIGH SCHOOL OR A HIGH SCHOOL EDUCATION	Count	36	1104	1140
	% within ACTIV2	22.6%	43.2%	42.0%
SOME COLLEGE OR A COLLEGE DEGREE OR BETTER	Count	123	1269	1392
	% within ACTIV2	77.4%	49.6%	51.3%
Total	Count	159	2556	2715
	% within ACTIV2	100.0%	100.0%	100.0%

Table 5. UNIVARIATE ANALYSIS OF THE INDEX MEASURING ACTIVIST BEHAVIOR\*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	4.00	25	.1	.9	.9
	5.00	134	.4	4.9	5.8
	6.00	455	1.3	16.7	22.6
	7.00	964	2.7	35.5	58.0
	8.00	1141	3.2	42.0	100.0
	Total	2719	7.7	100.0	
Missing	System	32565	92.3		
Total		35284	100.0		

\*See also the discussion of the dependent variable under the section on measurement and methods.

Table 6. PEARSON CORRELATIONS OF THE COMPONENTS OF THE ACTIVIST INDEX

	INDEX_B	PROTESTED FOR ENVIR ISSUE	SIGN PETITION ON ENVIR ISSUE	MEMBER OF ENVIR GROUP	GIVE MONEY TO ENVIR GROUP
INDEX_B	1.000	.370	.741	.566	.737
PROTESTED FOR ENVIR ISSUE	.370	1.000	.176	.233	.058
SIGN PETITION ON ENVIR ISSUE			1.000	.355	.494
MEMBER OF ENVIR GROUP				1.000	.301
GIVE MONEY TO ENVIR GROUP					1.000

TABLE 7. ACTIVIST BEHAVIOR REGRESSED ON PERCEPTIONS OF THREAT, LIFE SATISFACTION & EMPOWERMENT;  
CONTROLLING FOR SEX & EDUCATION

perceptions of threat	model 1 demographic portrait		model 2 perceptions of threat, concern for environment and demographic characteristics		model 3 saturated model with perceptions of threat, concern for the environment, psychological factors and demographic characteristics		model 4 with significant variables only	
	beta	p-value	beta	p-value	beta	p-value	beta	p-value
disagreement that pesticides used in farming are dangerous <i>for oneself and one's family</i>			-.052	.150	-.162	.006	-.163	.005
opinion that pollution of rivers, lakes and streams is dangerous <i>for oneself &amp; one's family</i>			.078	.001	.059	.130	.064	.095
opinion that pesticides used in farming are dangerous for the environment			.132	.000	.203	.000	.201	.000
<b>general concern for the environment</b> disagreement with statement that society worries too much about progress harming the environment			-.192	.000	-.132	.000	-.134	.000
<b>psychological characteristics</b> satisfaction with family life					-.069	.064	-.070	.054
satisfaction with friendships					.107	.004	.110	.002
empowerment					-.093	.012	-.098	.007
<b>control variables</b> education	-.249	.000	-.224	.000	-.218	.000	-.218	.000
sex	-.056	.003	-.028	.145	-.071	.034	-.071	.033
age	.006	.002	.047	.015	.027	.433		
race	.059	.765	-.019	.362	.006	.871		
number of children	.037	.076	.019	.360	.007	.840		
R <sup>2</sup> <sub>adj</sub>		.074		13.7		14.2		14.4
number of cases (N)		(2709)		(2436)		(817)		(817)

# The Poetic Brain: Neuroscience and Myth in the Poetry of Louise Labé and Pierre de Ronsard

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## Abstract

Today's neurosciences have long roots in early modern history, medicine, and culture. This study examines the invasion of sixteenth-century French poetry by the ideas and controversies about human neural anatomy, physiology, and psychology. It concentrates on two poets who differ from each other in gender, philosophical outlook, historical context, and writing style. Louise Labé's *Oeuvres* (1555) often evoke her female beloved, the male lover, and their psychology of love in terms of the intellect, passions, and affections of the brain. She extends her psychological theories to show how Platonic love between women and men results in creative writing. Pierre de Ronsard, especially in his *Amours*, (1552-1578) expresses the profound effect of love on his subjective reality when he experiences changes in his spiritus, heart, mind, and soul, all component parts of early modern metaphysics and medicine. But at the same time he denounces in his *Discours* (1560-1587) Protestant doctors, whom he considers disloyal, with parodic metaphors taken from their own medicine. The study finds that in the poetry the brain represents human mental, intellectual, and psychological faculties, individual and collective value, and even one's humanity as a whole.

Today's neurosciences have long and sinuous roots in early modern history, medicine, and culture, much of which centered on debates like Vesalius's critique of the Galenic brain in *De humani corporis fabrica* (1543). This study examines the invasion of sixteenth-century French poetry by the ideas and controversies about human neural anatomy, physiology, and psychology as found in the writings of two poets, Louise Labé and Pierre de Ronsard, who differ from each other in gender, philosophical outlook, historical context, and writing style. While previous studies have attempted to prove the scientific or proto-scientific origins of particular ideas in poetry by medical and clerical scholars, or to examine the use of medical rhetoric in creative writing, both legitimate objects of study, they are included only as part of the objective for the present study. This investigation attempts moreover to place these authors within the intellectual history of Western concepts of the brain and nervous system.

First, Louise Labé's *Oeuvres* (1555) evoke the female lover, her male beloved, and the psychology of their love, which are often seamlessly expressed within her four major works in terms of the intellect, passions, and affections of the brain. She also intermingles the psychological theories in the prose *Débat de Folie et d'Amour* and her *Epistre* to Mademoiselle Clémence de Bourges into her poetic *Sonnets* and *Elégies* to show how Platonic love, including the love between women and men in the Neo-Platonist tradition, results in creative writing. Second, Pierre de Ronsard, especially in the nine principal editions of his *Amours* (1552-1584), shows the profound effect of love on his subjective reality when he experiences changes in his spirit, heart, mind, soul, and brain, all component parts of early modern metaphysics and medicine.

This study contributes to intellectual history as evidenced in the works of these two poets about the importance that has been placed on the brain as the organ, origin, and locus in the body for thought, emotions, and movement in early modern French literature and culture. It finds in these and other works that the brain in early modern French poetry represents human mental, intellectual, and psychological faculties, individual and collective value, and even one's humanity as a whole.

While the debates over the Galenic versus the Vesalian brain raged in the mid sixteenth century, for most non-medical readers the brain and nervous system had been accepted in medieval psychology as the location of both the soul and its sensory and cognitive faculties. On this topic medieval anatomists and physiologists tended to follow Galen rather than Aristotle, who had placed these faculties in the heart and who had considered the soul to be "the place of forms."<sup>1</sup> Galen's soul was clearly located in the brain itself, and, in his view, the spirit filled the ventricles of the brain and had the ventricles operating as the spirit's instrument or conduit.

While Galen's anatomy had been the medical model, it apparently was overtaken in the Middle Ages by modifications of his theories on the inner senses or faculties, such as Avicenna's system of five faculties: the common sense (*sensus communis*), the imagination (*imaginatio*), the cogitative faculty (*imaginativa* or *cogitativa*), the estimative faculty or instinct (*aestimativa*), and the memory.<sup>2</sup>

The result is that, within the bounds of the accord that had to be struck between Christian theology and any such medical theories, medieval scholars viewed what today's experts call cognition, including memory, as processes that occur both through intermediary physiological mechanisms of the cerebral ventricles and through those operations that take place in the soul or mind.<sup>3</sup> Through the sixteenth century, debates about the brain and nervous system continued in medical theory. French poets, though unevenly knowledgeable about what scholars and university trained physicians argued, were committed to enriching their verse with encyclopedic knowledge about the natural world, especially after the admonitions about the necessity of learning the arts and sciences in *La deffence et illustration de la langue Française* (1549). The

resulting poetic works contributed to a more widespread literary expression of their own interpretations of medical theories and scientific ideas about how we perceive, think, feel, and move.

In the *Oeuvres* (1555), Louise Labé reveals a psychology of Platonic love in which the female lover and her male beloved are *âmes-soeurs*, soul-mates, who are united in a love whose prodigious psychological effect can be seen and represented in poetic terms. In her four major works she extends a set of psychological theories about love and writing expressed especially in Discourse V of her *Débat de Folie et d'Amour* to include a treatise on love and folly which describes their role in individual and group psychology with particular attention to their effect on the intellect, passions, and affections of the brain. In a reversal of Christine de Pizan's evolution from fiction and imaginative poetry to more serious philosophical prose treatises, Louise Labé's writings shift from poetry to prose.<sup>4</sup> Labé's writings change from the wide ranging theoretical debates in the dialogue form of the *Débat*, and in her letter, the *Epistre* addressed to Clémence de Bourges, both in prose, and evolve into a dazzling, creative, and persuasive poetry in the *Sonnets* and the *Elégies*.

### Mixed Metaphysics: The Case for Love

The *Débat de Folie et d'Amour*, *The Debate between Folly and Love*, is structured as a forensic debate for Jupiter to sit in judgment over whether Folly or Love should have had priority when entering the palace of the gods for a great feast. Its premise is to seek a juridical resolution to the altercation in which Folly blinded Cupid, who had dared to enter before her, and then she permanently banded the eyes of the little god of Love. As allegorical figures, Apollo and Cupid, here called Love, represent the distinct personalities attributed to them as Greco-Roman divinities and the consequences in the behaviors that they can inspire and guide in humans.

Apollo, god of prophecy, medicine, music, and poetry and known for art, philosophy, and learning, is a proper defender of Love in a Platonic or Neo-Platonic perspective on the joined episteme of the couple in love. In the trial, Apollo defended Love and all that Love had done for human history in front of Jupiter and the hall of divine guests. In Discourse V Apollo waxes into serious philosophical discourse on Love's contribution to humanity as both that collective love in the form of human sociability and affinity for the society of other human beings and the special, particular love that individuals have for one another.

### The Troubled Brain: The Case for Folly

Following Apollo's almost melodic and eloquent defense of Love, emphasizing its unity and harmony and showing the mood altering affections and the soul-transforming psychology that Love inspires, in the name of fairness, Mercury is called to defend

Folly against the tide of accusations in the great hall of paradise. The opposing sides of the debate continue to show the distinct personalities of mythological divinities and the corresponding psychology of those persons under their influence. Mercury, god of travelers, luck, music, and eloquence and known for wit and invention, is Folly's advocate, and Folly is the newly iconized personification of creativity, joy, and laughter in Erasmus's *In Praise of Folly* (1509). They become rhetorical figures for the set of ideas they espouse in the dialogue.

Mercury's seemingly rapid-fire discourse, quite consistent with his metaphorical and philosophical nature and personality, is based on Stoic metaphysics, ancient and medieval theoretical medicine, and empirical demonstrations in logic of Folly's work on the affections, the passions, and the brain. By nature more precipitous and hasty than Cupid ("plus pronte et hative"<sup>5</sup> Folly is reportedly endowed with an older provenance than Love, since Folly must be present in every individual at birth and in every society's earliest heroes.

Moreover, Folly is said to be owed greater authority than Love, not only because of Folly's priority over Love, but also because of the tremendous debt that humans and even their gods owe her for their greatest accomplishments. The flowing list of these gifts to human society and world cultures is a rhetorical torrent. Mercury recites Folly's ongoing list of accomplishments and honors. The discovery, cultivation, and trade in artifacts derived from the flora and fauna and produced from the earth and the seas is attributed to the singular vision and unique perspective that Folly inspires when she touches individuals so that they stray from the collective toward a separate, different path. Folly's touch stirs up the brain of those afflicted with its special gift, especially among the great ones: "*Folie ha fait les autres obéir. Folie ha inventé toute l'excellence, magnificence, et grandeur, qui depuis à cette cause s'en est ensuivie.* (Labé 86)" [Folly made the others obey (her). Folly invented all excellence, magnificence, and grandeur, which subsequently result from this cause (my translations throughout)].

The examples of these phenomenal individuals and their unprecedented, wholly original thoughts, words, and actions begin with Alexander the Great (Labé 86), who is followed in swift succession by a series of great philosophers as well as distinguished scientists and masters of a wide range of disciplines in the ancient world. All of them were touched in the head and agitated in their brain, according to the version of history used to defend Folly before her accusers. According to Labé's reinterpretation of medieval psychology, the personalities of these Greco-Roman gods and figures and the behaviors that they cause in mortals are also closely linked to the disturbances they cause and their untoward and unexpected consequences.

The argument in Labé's text is that the greatest thinkers are touched most profoundly by Folly, from birth to death. Among them are great minds like the Stoic Chrysippus (280-207 B.C.) and Aristotle himself (384-322 B.C.). "*Combien pensez vous qu'elle (Folie) ait de fois remué le cerveau de Chrysippe? . . . . . qui regarderoit*

*bien . . . trouveroit . . . comme leurs cerveaus estoient mal faits.*" (Labé 86-87). [How many times do you think that (Folly) shook the brain of Chrysippus? . . . whoever looked hard . . . would see . . . how (the) brains (of all the others) had been deformed.] Also included among those brains touched by Folly is Empedocles, the scientist, theologian, and cosmologist among the pre-Socratics in the 5th century B.C., who is credited with having established that the four elements of the universe were earth, air, fire, and water. In his world view the four basic elements change back and forth due to the influence of Love, as the unifying principle, versus Strife, as the fragmenting principle, all of which are motivated by the impetus of Chance and Necessity.<sup>6</sup> Represented as being similarly addled and touched in the head is Diogenes (412?-323 B.C.), the post-Socratic philosopher who founded the Cynics. He is known for having made it his mission to live and promote an ethic that resisted the oppression that comes under the rubric of artifice and convention in society and for setting as his goal the pursuit of virtue and the moral freedom gained by liberating oneself from desire.<sup>7</sup>

Refusing the straight and narrow ("*demeurer en chemin*" [Labé 87]), the gifted, inspired, talented, creative, and independent, according to Labé's dialogue go their own way until they meet a like-minded and equally dazed and brain-troubled person who values someone as different as themselves, "*Le fol ira tant et viendra, en donnera tant à tort et à travers, qu'il rencontrera en fin quelque cerveau pareil au sien qui le poussera : et se fera estimer grand homme.*" (Labé 87). [The fool will go forward and back and will do it at random, until he meets up with a brain similar to his which will force him and make him see himself as a great man.] Folly likewise refuses the temporary, hidden, and isolated pleasure of individual love, a pleasure which quickly fades into boredom and, what is more, results in a bad headache, according to Mercury's indictment of Love's weakness and lack of respect and authority. Obviously, Folly's disturbances of the brain cause corresponding psychological disturbances. But rather than result in maladies related to the brain, sense organs, or faculties that Galen described in *De locis affectis* [On Affected Parts], *De temperamentis* [On Temperaments], and *De naturalibus facultatibus* [On the natural faculties], in the *Debate* Folly's effects on the brain of certain individuals are a result that is good for every society, its collective knowledge, and its culture.

The close of Mercury's argument in favor of Folly, its priority, and authority provides solutions to the problems caused by Love, and remedies to the agitation, disturbances, and disharmony in the solitary, unreciprocated lover's temperament. All of this leads Mercury to make one final admission before submitting the case of Folly against Love for Jupiter's final judgment. In the theoretical anatomy, physiology, and medicine of Love and Folly, Mercury concedes in open court that the two are inseparable, "*Amour donq ne fut jamais sans la compagnie de Folie*" (Labé 101), [Therefore, Love

has never been without the company of Folly].<sup>8</sup> In his position as final arbiter and judge, Jupiter postpones his verdict to some far off future time and in the meanwhile sentences Folly to guide the blinded Cupid wherever he (or wherever she)<sup>9</sup> seems to want to go.

Where Love is a tender and apparently Christian feeling and emotion that affects people, both collectively in their cohesive groups and individually in intimate dyads and married couples, Folly, though commonly shared in laughter and humor, remains singular in its effect on the brain, soul, and spirit of the individual. Folly makes the individual, separate himself from the others, because the brain is uniquely agitated and refigured at birth and for the rest of that person's life. Drawn from the prose *Debate of Folly and Love*, this description of the metaphysics and physiology of love and folly is interlaced throughout Labé's poetry of the *Sonnets* and the *Elegies*. In the first lines of the final *Elegy* III, there is expressed that same perpetually haunting desire for the beloved as seen in the lover's lament about, "*mes regrets, ennuis, despits et larmes*" (Labé 115) [My regrets, woes, resentments, and tears]. There is likewise her grief for the lost beloved, that intellectual, spiritual soul of the poet-lover's body, which she seeks longingly in Sonnet VII, "*Lors que du corps l'ame sutile part . . . Ou es tu donq, o ame aymee?*" (Labé 124) [When from the body the subtle soul departs . . . Where are you then, oh my beloved soul?]. And there is the head of her beloved, her world in microcosm wherein are the brain and soul, a sight which inspires her impassioned heart in Sonnet X (Labé 126), "*Quand j'aperçoy ton blond chef couronné . . . Au chef d'honneur plus haut que nul ateindre*" (Labé 126) [When I espy your crowned blond head . . . (Head) of (such high) honor that none can attain].

These concepts and metaphors in Labé's poetry relate to parts and functions of the brain and nervous system, and they all reflect ideas and principles elaborated in the *Debate*. Furthermore there is a fluid reciprocity of these ideas and concepts in the prose and the poetry. In other examples, the beauty, joy, curiosity, and singular path along the Euripa River taken by the enamored lover in Sonnet XIII are reminiscent of the inexplicably violent currents of the Euripa River that confused, angered, and frustrated Aristotle as to their source to the point of madness, as explained in the *Debate*. The Euripa River's violence first in the prose dialogue and then in verse is a metaphor both for the troubled episteme of the lover and her beloved when they are forced apart and for the mental derangement experienced by the wisest man or woman before the greatest unknown or intellectual challenge. The suffering caused by love and the madness caused by an insoluble problem are made analogous. Such ideas about the brain, nervous system, and their operations and also such analogies shared between these two genres are found throughout Labé's prose and poetic works.

The anatomy and physiology of Labéan neuroscience form an eclectic mixture of Stoic, Aristotelian, and Galenic theoretical medicine and empirical logic with her own

version of Neo-Platonist and Platonist metaphysics. This combination of medicine and metaphysics permits Labé's writings to make the radical poetic shift in gender from the male lover to the female lover and make the decisive transformation from accepting the domestic limitations of a woman's education to expanding women's participation in culture and society to include the power and mastery that comes with humanist education, heretofore reserved for men. As a result of her medical and metaphysical justifications, it becomes possible for Louise Labé and women like her to set down in writing, first perhaps in prose and eventually in poetry, women's learning and creative ideas and enter along this path the realm of letters, arts, and sciences.

### The Aesclepiades: The Brain Taken From Ancient Greek Medicine in Ronsard's *Amours*

Ronsard's poetry has long been considered encyclopedic in the depth and breadth of the poet's knowledge about the physical and metaphysical world, and his knowledge of the arts and sciences of his day has been recognized and examined, especially the *Hymnes*.<sup>10</sup> The questions for this study on neuroscience are concerned with whether and in what manner Ronsard's *Amours* (1552-1584) represent the brain and nervous tissue in the intellectual history of his era. What medical theories on topics in neuroscience do his poems present? An examination of a select few of Ronsard's *Amours* can be very revealing about the poet's neuroscience and its place in early modern French intellectual history. The reason for choosing the following poems is that they point directly to Ronsard's medical orientation and the theories that are most consistent in his representation of the brain, nervous system and mental operations.

Ronsard's refutation of Platonist philosophy, cosmology, and metaphysics parallels his refutation of Petrarch, and, not surprisingly, continues unbroken in his neuroscience. The mind-body problem in his *Amours* is not resolved with the categorical separation of the spiritual, immaterial soul separated by its nature from the physical, material body. Sonnet XLII of the *Premier Livre des Sonets pour Helene* (1578) is clear illustration of this refutation of Platonist metaphysics and its valorization of the soul, the intellect, theoretical education, and the philosophy of ideas and forms.

Bien que l'esprit humain s'enfle par la doctrine  
De Platon, qui le chante infusion des cieux,  
Si est-ce sans le corps qu'il seroit ocieux,  
*Et auroit beau vanter sa celeste origine.*<sup>11</sup> (Ronsards 407)  
[While the human spirit might be so inflated by the doctrine  
Of Plato, who carols it as the (nervous) influx of the heavens,  
Is it so bodiless as to be indolent,  
And (not) so very fine praise to its celestial origin(?)]

This refutation pushes Ronsard's critical analysis of the separation of body and soul to the point of accusing Plato, for his concept of the rational soul separated from the living body, of being a fraud and purveyor of dreams, chimeras, or mythical stories about dashed hopes and aspirations.

But the neuroscience represented in the *Amours* goes beyond refutation of the basic ideas in Platonist metaphysics and goes on to advocate a particular theoretical medicine. In Sonnet XXXVI the frustrated narrator "*je*" calls out to the "barber," the title then for a practicing medical doctor without university credentials, and the troubled narrator pleads for the figure of the barber-physician to heal his beloved of her antipathy and cold-heartedness toward him.

*Gentil barbier, enfant de Podalyre,  
Je te supply, seigne bien ma maitresse,  
Et qu'en ce mois, en seignant, elle laisse  
Le sang gelé dont elle me martyre.*  
[Kind barber, son of Podalirius,  
I beg you, bleed my mistress well,  
And (in a month), by bleeding her, (she will release)  
The icy blood which makes her torture me.]

Here Ronsard's beloved goes unnamed but the lineage of the doctor called to treat her anti-love sickness is clearly known, the son of Podalyre, as noted in modern editions, a version of the name Polidore, one of the two sons of the legendary Aesculapius or Aesclepius.<sup>12</sup>

The poet-lover begs Podalirius, doctor and warrior,<sup>13</sup> to bleed his mistress of her cold blood and, with it, her cold-heartedness, so that the remaining warm blood, "*le sang plus chaud*," will inspire her to love him. Desperate for a cure, Ronsard's narrator is willing to risk her death, and to risk his own spiritually, with a widely accepted metaphorical remedy. However, the bleeding Podalirius administers is taken to the extreme.

Where Ronsard's beloved recedes into the background, Ronsard's doctor is begged and called out to find a cure for her diffidence and harshness. Among the ancient Greek poets, Apollo was the god who founded medicine, and he first established methodical medicine, which pursues remedies and incantations. Known as the son of Apollo and Coronis, Aesculapius learned medicine from Apollo. Divine healer and the object of his own religious cult, Aesculapius is the founder and patron of ancient Greek medicine, whose renown warranted both disciplined study and worship. Aesculapius followed in his father's footsteps in the healing arts and sciences, and he invented empiric medicine, which was based not on indications and signs but on experience alone. Hippocrates only later invented rational medicine based on observation and dissections.<sup>14</sup>

In the end, the remedy seems to be going too far and the poet-lover demands that the barber-doctor stop upon seeing how the lady beloved was bled so much until there was no warm blood to find. Particularly significant for Ronsardian neuroscience is the fact that among the earliest antecedents of Western medicine is the medicine of the famous ancient Greek poets, as found in the writings of Homer and Hesiod, which long predates the Socratic era. Medicine of the poets was founded on vital breath, the *spiritus*, or *anima* as the principle of animal life, on the one hand, with animal spirits in the blood and an individual moral consciousness as intermediaries and vehicles to the living physical body, on the other hand.<sup>15</sup> It seems only fitting that Ronsardian neuroscience circumvents the debates and controversies of his contemporary medical theorists, who are mere mortals. Apparently, it takes mythical doctors to heal the epic soul and brain in his poetry.

Ronsardian neuroscience per se is more explicitly revealed in Sonnet XX of the *Premier Livre des Sonets pour Helene* (1578) where the human head is praised as the origin and locus of mental faculties such as thought, feelings, emotion, and the reasonable and eternal Christian soul. In this sonnet Ronsard's narrator initially calls the head the source of art and learning:

*Chef, escole des arts, le sejour de science,  
Où vit un intellect, qui foy du Ciel nous fait,  
Une heureuse memoire, un jugement parfait* (Ronsard 396)  
[Head, school of the arts, seat of knowledge,  
Where intellect resides, which heavenly faith creates in us  
A blessed memory and perfect judgment.]

In swift succession the metaphorical names for the head cascade from verse to verse: "habitat of intellect"—"maker of heaven-sent faith"—"the resting place of blessed memory and perfect judgment"—"second birthplace of Pallas Athena"—"locus of honor, virtue, and prudence"—"supreme enemy of vice"—"small universe which holds perfect knowledge of the great All"—"all timely and subtle, all circular and all within yourself." The metaphors, or other names in Aristotelian poetics, for the head demonstrate the Aesclepionic influences in Ronsardian neuroscience and point to an aesthetic commitment to the ancient Greek theogony or theology of Homeric and Hesiodic literary sources<sup>16</sup> for his psychology.

In this study of neuroscience in the works of two poets in such sharp contrast, Louise Labé's *Oeuvres* resolve the psychological dialectic between the allegorical Folly and Love, that is both the neural effects and the behaviors they produce. In the *Debate* there are contending positions between Platonic metaphysics on love versus ancient Greek and Roman mythology theoretical medicine on Folly, especially the Stoics on emotion, passions, affections, and the seat of the soul. In addition there is due tribute to contemporary philosophy, in particular Erasmus's *In*

*Praise of Folly*. In her *Oeuvres*, the *Sonnets* and *Elegies* represent the resulting dialectical unity at the end of the *Debate* between two opposing sides of similarly compelling value and authority that form the theoretical basis of her poetry. At the conclusion of the *Debate* there is an ambiguous but intriguing dynamic created in combining love with folly that suggests that, in the allegory of Lady Folly leading through the world for the foreseeable future little Cupid, the blinded archer, human beings always have the capacity for both greatness and happiness, because of the joy and intellectual and emotional harmony in pairing the two, on the one hand, and because of their creative discord and imaginative tension, on the other.

In Pierre de Ronsard's *Amours*, the poet's neuroscience is based on Aesclepionic medicine, both the historical and the legendary, whose ancient medical theories and practices the poet clearly prefers over the controversies, weaknesses, and uncertainties of Renaissance anatomists, physicians, and medical doctors. In the voice of the poet-lover, the author of the *Amours* deliberately ignores all of the theoretical and practical medicine of his contemporary physicians and doctors in favor of the intellectually and morally superior form of ancient theologically based medicine. Because Ronsardian neuroscience is based on principles laid down by the Greek gods who founded medicine, by the mythic physician healers who descended from them, and by the ancient medical warrior-doctors who established divinely guided medical traditions, their theories and practices of divine medicine regarded by the Ancients serve as suitable metaphors to represent the poet-lover's visionary outlook, his experience, and his masculine subjective reality.

The poetic examples considered here point to the distinct choice by each author of certain theories and particular sources and uses of philosophy and theoretical medical knowledge about the brain and its functions. Interestingly, while Louise Labé and Pierre de Ronsard were in their own way distant from contemporary theories about the Galenic brain and Vesalian neural anatomy, and each poet looked instead to different well regarded ancient philosophers or classical Greek and Roman literature for their neuroscience, both of them, quite logically as poets, addressed concepts and theories about the brain and nervous system that were involved in the process of writing and its mental, emotional, perceptual, neural sources and inspiration. While the terms for the structures and concepts of the operations of that part of human life which thinks, feels, perceives, and wills changed rapidly in the sixteenth century, the brain and nervous system became a shared object of investigation and discussion by French writers in this period. Louise Labé and Pierre de Ronsard are two poets whose views on neuroscience are both striking and impressive.

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## Notes

1. Simon Kemp, *Medieval Psychology*. Contributions in Psychology, 14. New York and Westport, CN: Greenwood Press, 62. This work provides a summary history of medieval psychology and its textual sources.
2. Kemp, 53-59.
3. Kemp 71.
4. Deborah Lesko Baker, *The subject of desire: Petrarchan poetics and the female voice*. In Louise Labé (1966), 2, treats throughout desire as "activity" and "problem," and 41-89, concentrates on the implications that result from the evolution of and relation between Labé's prose and her history.
5. Rigolot, 68. Translations throughout are by Clark-Evans.
6. Bertrand Russell, 55.
7. Russell, 231.
8. Rigolet, ed., 22, describes this point in Mercury's defense of Folly a union of opposites, "*une alliance des contraires, une coincidentia oppositorum*," between love and folly.
9. According to Rigolot (ft.2), the passage (Labé, 103) is ambiguous about whether Cupid or Folly decides where they will go.
10. M. Bensimon, 266-290; G. Gadoffre, 45-48; and A-M Schmidt are among the most prominent works on Ronsard's scientific poetry in general. Schmidt, 95-138, examines in depths the *Hymnes* (1555-1556) and concludes that Ronsard's cosmology and his metaphysics, based on Neo-Latin authors and Stoic principles, produce a germinal epistemological synthesis between scientific thought and poetic discourse, whose heritage continued through the second half of the sixteenth century. Patin, in Lazard, ed., 187-214, has done among the most important contemporary studies of Ronsard's *Hymnes*, and her *Les Amours et leurs 'noeuds de philosophie: Un aspect de l'Attitude de Ronsard envers la tradition Pétrarquiste*, 49-56. has examined the esthetic philosophy in the *Amours*.

11. Pierre de Ronsard, *Les Amours*. Henri et Catherine Weber, eds. (1998) Paris: Classiques Garnier, 407.
12. Ronsard, 193, in ft. 2 to this citation has already noted that the black blood refers in the theory of temperaments to a melancholy individual and emulates Marot on bleeding the beloved and Homer on the name of the medical doctor in question.
13. J. H. Baas, M.D., (1971) *Outlines of the history of medicine and the medical profession*, trans. And rev. by H.E. Henderson, M.A., M.D. Huntington, NY: Robert E. Krieger Publishing Co., Inc., I, 86.
14. *Asclepius. Collection and interpretation of the testimonies*, E. and L. Edelstein, ed. (1945) Baltimore and London: The Johns Hopkins University Press, rpt. 1988. xxii, 182, 186.
15. Ronsard, 396, in ft. 2 to this citation the editors Weber have already noted that black blood refers in the theory of temperaments to a melancholy individual and the poem emulates Marot on bleeding the beloved and Homer on the name of the medical doctor in question.
16. Chaignet, I, 5-6.

# The Playhouse as Plaguehouse in Early Modern Revenge Tragedy

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## Abstract

Outbreaks of the plague in early modern London evoked a plethora of prose works that attempted to explain the moral and medical reasons for the plague's "visitations." However, there are no significant analogous developments in the theatre of the period. This paper addresses the question, "Where are all the plague plays?" by examining revenge tragedy as one possible site of the plague's impact. The plots of *The Revenger's Tragedy* and Ford's *The Broken Heart* follow the pattern of a plague outbreak, in which one "infected" person causes the stage to be littered with bodies by the final scene. In addition, early modern beliefs about the plague's causes and effects are reflected in the plots of these tragedies. On a meta-theatrical level, revenge tragedy configures the playhouse as a plaguehouse: "quarantined" within the world of the play, characters have no guarantee of survival, only that the casualties will be high. Reading these plays through the discourse of infection not only has implications for our understanding of this particularly violent sub-genre of tragedy, but it also offers new insight into the intimate connections made by early modern medicine between the mind and the body, between the physical and the emotional.

A survey of the bills of mortality for London in the early seventeenth century reveals the heavy impact of plague on the urban populace. By F. P. Wilson's estimates, the population of London was 250,000 in 1603 (Wilson 114). In that year, the bills of mortality record the deaths of 30,578 by plague (Wilson 114). The second major outbreak of the period in 1625 took 35,417 lives (Wilson 211). London's population in that year is estimated at 320,000 (Wilson 174-5). Between these two outbreaks, the plague struck with varying intensity: the years 1604-1611, for example, saw the additional deaths of more than 13,000 people by plague (Wilson 210).

But we do not need to rely exclusively on statistics for information on how terrible the plague was. In *The Wonderfull Yeare*, written in response to the 1603 outbreak, Thomas Dekker wonders,

For he that durst ... have bene so valiant, as to have walkte through the stil and melancholy streets, what thinke you should have bene his musicke? Surely the

loude grones of rauing sicke men: the strugling panges of soules departing: ... here he should have met some ... fear-fully sweating with Coffins, to steale forth dead bodies, least the fatall hand-writing of death should seale up their doores.... The dreadfulnessse of such an houre, is in-utterable. (27-28)

Dekker's anecdote of furtive attempts to remove the corpses from family homes in order to avoid quarantine illustrates the desperation and terror of plague time. George Wither's *Britain's Remembrancer*, a response to the 1625 plague, reveals that even mundane activities became regarded as potential sources of infection as it reports a rumor of infected pigs in the marketplace:

Some, to frequent the *Markets* were afraid;  
And some to feed on what was thence purvay'd.  
For on young pigs such purple spots were seene,  
As markes of Death on *Plague*-sicke men have been. (Wither 134)

Early modern print practices made possible swift and comprehensive responses to the plague. Plague years sparked a variety of printed responses, including sermons, medical treatises, and literary responses such as Wither's and Dekker's. These texts feature innumerable details of the effect of plague on early modern bodies and culture, and signs indicating the likelihood of its recurrence. They are evidence of a culture that was repeatedly traumatized on a mass scale by this unpredictable and deadly disease.

Current studies of the drama of the period, however, largely fail to consider the impact of plague on theatrical activity. This lack is in part attributable to what Leeds Barroll describes as "the traditional picture of ... a flourishing and uninterrupted enterprise," during which "Plays, presumably, were there to be seen every afternoon for year after sunny year" (172). By his calculations, however, theatres were closed for 71 months from 1603 to 1613 (173). It is unquestionable that the plague had a significant impact on theatrical activity.

However, the lack of critical attention to this aspect of early modern theatre is also attributable to the fact that playwrights of the time seem to have failed, for the most part, to register the plague experience in the plays themselves. While critics have noted the ubiquitous use of pestilential language in the period, there are very few plays which treat plague as part of their plots—that one could say are *about* the plague. In an era in which theatre achieved an unprecedented level of psychological realism, and began to use contemporary settings and subject matter, Jonson's *The Alchemist* (1610) stands out as one of few plays that uses a London plague outbreak as the backdrop for its action. Middleton's *Your Five Gallants* (1608) also reflects the experience of the plague in a scene in which "a London broker conducts his business with a bill of mortality by his side," rejecting and accepting pawns based on the level of infection in the applicant's neighbourhood (Wilson 109-110).

However, these examples still leave us with the question, "Where are all the plague plays?" It was with this question in mind, as well as the question of how these plays might be found, that I attempted to theorize how mass trauma impacts popular entertainment. I thought about recent world events. One could not escape news coverage of September 11 following the events of that day; however, Hollywood immediately delayed the release of several films that had plots involving terrorism, bombs, or airplanes in danger.

But this does not mean that September 11 failed to register in popular entertainment. A year and a half later, it seems evident that these events continue to be presented to audiences in filtered ways that enable them to take on some additional meanings. M. Night Shyamalan's *Signs*, for example, began filming on September 12, 2001 (*Signs* DVD 2002). It features an alien invasion as it is experienced by a rural family. The family obsessively and helplessly watches coverage of the invasion on television, but eventually gets to play their own part in defending themselves by physically beating and defeating one of the invaders when it threatens the life of the main character's young son. The analogies to the terrorist attacks seem obvious, but more important for my purposes is the fantasy of agency the film builds, a reassuring vision of the individual's ability to take action in the face of an overwhelming threat.

These observations opened new possibilities for examining the intersections of the early modern plague experience and theatre. If popular entertainment does act as a form of filter, presenting traumatic events to its audiences in a less terrifying form, then what it does with the raw material of traumatic experience will also be revealing of how that culture manages trauma. Having suffered the mass trauma of plague, what sorts of fantasies does early modern culture present to its theatrical audiences?

Revenge tragedy seems an obvious candidate for a site of the plague's impact because of its biologically graphic plots: a single character's thirst for blood in the beginning of the play results in a stage littered by bodies at the end. Thus some revenge tragedies may be said to be *about* the plague insofar as they reflect the narratives constructed by early modern discourse to explain the plague—the reasons for its presence in human societies, the methods by which it was transmitted, and the ways in which it killed. Early modern medical and religious authorities viewed plague as intimately connected with ideas of divine retribution and a variety of human weaknesses, particularly emotional imbalances, that made the individual more susceptible to infection. These traits, the need for retribution and emotional imbalances that render the body vulnerable, are important factors in the plots of revenge tragedy.

William Muggins's *London's Mourning Garment* (1603) demonstrates some of the psychological impacts of idea of plague as divine punishment. Narrated by London personified, Muggins's poem begins with a depiction of the city in a state of happy anticipation of the newly crowned James. In this case, the outbreak is viewed as punishment for the pride London shows in displaying her wealth. By collapsing the collective

of London society into the single persona of London, Muggins subsumes individual crimes under the aegis of society as a whole. It is society as a whole, then, that incurs the wrath of God. As the rest of the poem emphasizes, it is part of the insidious nature of plague that it does not necessarily punish those who are most deserving. Rather, plague strikes randomly. London reminds her audience that

... to the ende, none dwelling in my Cittie  
Should think themselves more safer than the rest,...  
Gods judgements upon all degrees are prest.  
(C3v)

Plague threatens to punish *anyone* potentially, while taking away the individual's control over the cause of that punishment. It necessarily evokes feelings of helplessness that are already present in a culture heavily invested in notions of providence and predestination. In this context, revenge tragedy may operate to mitigate this sense of helplessness by temporarily placing the power of life and death in the hands of a human being, the revenger. For the duration of the play, the revenger is imbued with an at times almost supernatural ability to hide in plain sight, well enough and long enough to avoid punishment until his vengeance is accomplished.

More importantly, the revenger operates as a kind of walking infection, a site of injury that proves deadly to the characters who share the stage with him. The revenger acts out of a past experience of deep personal injury, a condition that marks him as metaphorically infected. There is an etymological association between "plague" and "wound". This is noted by Margaret Healy in her superlative *Fictions of Disease in Early Modern England* (2001). This association suggests a particularly violent injury, since as Healy notes, "The English 'plague' derives from the Latin word 'plaga' meaning 'a blow, a stroke, a wound' (OED2 [1])" (Healy 55). The revenger's wound is emotional, but the connection between woundedness and plague is an intimate one.

Indeed, the connection between negative emotions and vulnerability to plague is commonplace in the period. Simon Kellwaye's 1593 treatise "A Defensative Against the Plague" advises that one should "Beware of anger, feare, and pensivenes of the minde, for by their meanes the body is made more apt to receive the infection" (E1r/p. 13). Francis Hering offers a more detailed explanation of the interactions of emotion and infection: "Eschue all perturbations of minde, especially anger and feare. The one by heating the body opens a doore for the enemie to enter: the other by cowardly running away gives him encouragement to tread on the hedge, which lyeth lowest, and maketh least resistance" (B1r). An emotional habit, especially a negative one, causes the humoural composition of the body to skew in one direction or another, potentially unbalancing one's disposition. An unbalanced disposition was thought to combine with exogenous disease factors to create a

diseased body: "it is not only the venomous and contagious ayre which we receive that doth kill us, but it is the present communicating of that contagion, with some superfluous humors in our bodies," Simon Kellwaye writes (D1v).

The relation between emotional imbalance and disease is particularly significant when we consider the emotional composition of the revenger. About to discover the body of his son Horatio, an event which will begin his career as a revenger, Hieronimo in *The Spanish Tragedy* (1587) asks, "What outcries pluck me from my naked bed, / And chill my throbbing heart with trembling fear" (2.4.63-64). Being of a vengeful disposition is associated with plague symptoms by other writers in the period. In Emblem 8, Book 1 of his *Emblems, Divine and Moral* (1635), Frances Quarles writes,

The world's a popular disease, that reigns  
Within the froward heart and frantic brains  
Of poor distemper'd mortals, oft arising  
From ill digestion, th' unequal poisoning  
Of ill-weigh'd elements, whose light directs  
Malignant humours to malign effects:  
One raves and labours with a boiling liver;  
Rends hair by handfuls, cursing Cupid's quiver;  
Another, with a bloody flux of oaths,  
Vows deep revenge.

(25-26)

The association between revenge and bloody flux is particularly suggestive of plague: Kellwaye devotes a substantial section of his treatise to the treatment of flux, excessive bleeding from the orifices or from plague sores or buboes.

In addition to the emotional and psychological aspects of the plague experience, it is important to recall that the plague as divine retribution inevitably evoked the idea of apocalypse. In *Britain's Remembrancer*, Wither mythologizes the 1625 plague by explaining that this visitation was the result of a divine compromise. In Canto 1 of that work, God decides to purge Britain of its sinful population by sending the Four Horsemen of the Apocalypse. Mercy pleads on Britain's behalf for no punishment; Justice accuses Mercy of being a soft touch, and in the end, they agree to send Pestilence as a Divine slap on the wrist for Britain's sinful populace. As we shall see, revenge tragedy, like plague in Wither's poem, likewise emulates the apocalyptic scenario without ultimately producing it.

\* \* \*

By these criteria, I view *The Revenger's Tragedy* (1606) as a prime candidate for pestilential theatre. This play emulates the apocalyptic through the figure of Vindice, who bloodthirstily takes back his sense of agency by murdering the evil, lecherous Duke who stole it away. Simultaneously, Vindice tests and then spares from death a variety of other characters, including his mother and sister. From the beginning of the

play, Vindice places himself in the position of judge. In the opening scene, Vindice performs a running commentary while the courtly characters pass across the stage like a parade of sins:

Duke—royal lecher! Go, gray-haired adultery;  
 And thou his son, as impious steeped as he;  
 And thou his bastard true-begot in evil;  
 And thou his duchess that will do with devil;  
 Four ex'lent characters.

(1.1.1-5)

The staging of this scene supports the notion that Vindice is somehow apart from those he judges. He can see them, but they can't see him. Throughout the action of the play, Vindice displays the revenger's (and disease's) ability to hide in plain sight. Disguised as the pander Piato, he infiltrates the court, gains the trust of various courtiers, and eventually poisons the Duke. Like the death that haunts the city in *London's Mourning Garment*, Vindice "Rageth up and downe, / And secretly, his heavy visage shewes" (Muggins B3v). These transformational and judging capabilities further echo early modern fears and fantasies about the plague. As Wither observes, "The Pestilence doth show herself inclin'd / So variously, she cannot be defin'd ... It is a rational Disease, which can / Pick, with discretion, here and there a man" (116).

However, Vindice's identity as apocalyptic equalizer, sparing the saved and avenging himself against the damned, unravels as the pestilential avengers multiply ridiculously in the final scene of the play. Here two separate sets of murderous masquers plan to kill everyone at the head table. The leader of the second set of revengers, the Duke's bastard son Spurio, possesses in an almost primal form Vindice's lust for blood: "I feel it swell in me," he says, speaking of his need for bloody vengeance as if it were a physical ailment. "My revenge is just; / I was begot in impudent wine and lust" (1.3.189-190). In the final scene, when Spurio and his gang find the job of murdering Lussurioso and his supporters already done, they fall upon each other in an unprecedented stabfest. Rather than creating the finality promised by the apocalypse, whereby the fallen and sinful are separated from the saved, the revengers' plans result only in piles of bodies, with the ambiguously benevolent Antonio becoming the new duke. His final words by no means suggest an end to the violence and bloodshed that has occupied the action of the play: "Bear up/ Those tragic bodies; 'tis a heavy season./ Pray heaven their blood may wash away all treason"(5.3.126-8). In the world of *The Revenger's Tragedy*, there are no guarantees that the cycle of sinfulness and retribution is over.

After entertaining the fantasy of finality, the play collapses it, as Vindice confesses to killing the Duke. Up until this point, it looks like Vindice and his brother are literally getting away with murder. Trying to justify his confession to Hippolito, Vindice argues that "'Tis time to die, when we are ourselves our foes" (5.3.109). If we follow the

pestilential logic of this play, we might be able to resolve Vindice's decision to confess. Having participated in bloody acts of vengeance, he himself has become one of the enemy, a diseased member of society who deserves judgement because of his emotional imbalance.

\* \* \*

A similar logic governs the death of the revenger Orgilus in Ford's *The Broken Heart*, probably composed in the late 1620s and published in the early 1630s. From 1621 to 1624 Ford collaborated on five plays, two of which are extant. His main collaborator was Thomas Dekker—Ford and Dekker wrote *The Witch of Edmonton* in 1621 with William Rowley. However, the later 1620s into the 1630s sees Ford going independent as he writes *The Lover's Melancholy*, *'Tis Pity She's a Whore*, and *The Broken Heart*. In these three plays, Colin Gibson identifies what he calls an "extraordinary burst of imaginative energy" (78). In *The Broken Heart*, Gibson notes in particular the remarkable scenes of bloodletting, but attributes to the play "an almost exemplary range of types of death" (68). Particularly noteworthy is the fact that the two phases of Ford's career, the collaborative and the independent, are separated by a plague year, 1625. This fact is a key to understanding the variety of deaths that occur in *The Broken Heart*, and to opening the text's emotional dynamics to new understanding.

Like *The Revenger's Tragedy*, this play is rich in images of disease. Telling his father Crotolon he has returned from Athens, Orgilus complains that there was an outbreak of the plague there. His father replies,

I fear  
Thou hast brought back a worse infection with thee—  
Infection of thy mind, which, as thou sayst,  
Threatens the desolation of our family.

(Ford 3.4.43-46)

Of course, the play traces precisely the destruction of Orgilus's family, as Orgilus's actions precipitate devastating madness and death in the Spartan court.

Indeed, this play is remarkable for its emulation of the various methods by which plague kills. The storyline is this: Penthea is betrothed to Orgilus, but because of a former political dispute, her brother Ithocles marries her to the jealous Bassanes. Ithocles loves Calantha, who is next in line for the Spartan throne. Penthea and Ithocles reconcile their differences and she agrees to help him win Calantha, after which Penthea, forever separated from Orgilus, pines and dies. Orgilus takes his revenge by transforming Ithocles into a sort of fountain of blood, killing him. Hearing the news of Penthea's, Ithocles's, and her father's death (of natural causes), Calantha dies, but not before she marries the dead Ithocles. Orgilus chooses to be his own executioner, piercing his own veins, and thus also emulating the bloody flux commonly associated with death by plague.

Perhaps even more than *The Revenger's Tragedy*, *The Broken Heart* participates in the notion that emotional injury is not only deadly, but also transmissible from person to person. The reconciliation scene between Ithocles and Penthea is full of the language of contamination and illness. Ithocles has earlier expressed his sense that he has injured himself through his actions: he attributes to himself "the sickness of a mind /Broken with griefs" (2.2.12-13). Part of Ithocles' apology to Penthea includes the idea that his sickness of mind has been transmitted to her: he says,

my rash spleen  
Hath with a violent hand plucked from thy bosom  
A lover-blessed heart, to grind it into dust,  
For which mine's now a-breaking.

(3.2. 43-46)

In return for his apology, Penthea promises to help him win Calantha, "If sorrows / Have not too much dulled [her] infected brain" (116).

The emotional damage dealt by Ithocles operates within a complex of meanings that involve disease and disposition. As Margaret Healy points out, dispositions were considered by some medical writers to be contagious. She writes, "The words 'contagion', 'corrupt', 'defile' and 'malignant' are all potentially functioning in the moral/psychic, as well as in the physical (disease-transmission) domain" (41). Rather than viewing this as an occult or supernatural notion separate from the idea of disease transmission, I am interested in the ways in which these two discourses might have been thought to be identical—in other words, since disease factors and negative emotions were both considered infectious in the period, and both operated to harm the bodies they infiltrated, I suggest that they might operate as equivalents to each other. So *The Broken Heart* might be considered a play 'about' plague insofar as it is about the transmission of fatal emotions from one character to another.

This transmission is perhaps most clear in the case of Calantha. She appears to survive the news of the deaths of Penthea, Ithocles, and her father, whispered into her ear during a celebratory dance. However, Calantha announces to the court that she knows she is dying:

O, my lords,  
I but deceived your eyes with antic gesture  
When one news straight came huddling on another  
Of death and death and death. Still I danced forward;  
But it struck home, and here, and in an instant....  
They are the silent griefs which cut the heartstrings;  
Let me die smiling.

(5.3.67-76)

Calantha's death stages early modern fears, supported by stories from plague time, of the possibility that one might drop dead suddenly and without warning. The forms of plague death, as Wither reminds us (in poetry not nearly as beautiful as Ford's), are many and unpredictable:

Some are tormented by it, till we see  
 Their veines and sinewes almost broken be,  
 The very soul distracted, sense bereft,  
 And scarce the smallest hope of scaping left ...

Othersome, againe  
 Fall suddenly; or feele so little paine  
 When they are seized, that they breathlesse lye,  
 E're any dying Symptomes, we espy.

(51)

In *The Broken Heart*, the revenger functions to spread death throughout the Spartan court in a variety of ways. Despite the characters' better intentions, as expressed through the attempted reconciliations between Ithocles, Penthea, and Orgilus, the damage has already been done, and death is already on its way. Emotional damage in this play operates like an infection, outside the will of those who unwittingly spread it.

My research will continue to pursue the implications of the interconnectedness of emotion and disease in the period, particularly with regard to the possibility that the idea of the broken heart entails more than just an emotional injury. We tend to read the broken heart as a description of woundedness in love, and thus exclusively emotional, and the deaths that result from these emotional injuries as hyperbolic expressions of romantic ideals. However, we might also consider information from plague literature, such as Dekker's notion in *The Wonderfull Yeare* that the broken hearts of the English populace upon the loss of Queen Elizabeth made them more susceptible to plague, or the many references in plague treatises to the need to keep the infection away from the heart, as the infection of this organ in particular will instantly end the life of the patient. The emotional dynamics of these plays might be opened to new insight by reading them through discourses of disease as ways to work through the conditions of life during plague time, rather than merely as records of doomed romantic entanglements.

The plague experience, the cultural function I believe these plays are performing, and the activities of playwrighting and playgoing seem intimately connected through the genre of revenge tragedy. *The Revenger's Tragedy* and *The Broken Heart* entrap their characters in claustrophobic court settings which emphasize the notion that "no one gets out of here alive"—a concept that would have been more than familiar to the poorer members of the theatrical audience, as they would have been unable to flee the city in times of infection. The boundaries between emotion and physical infection, between playhouse and plaguehouse may have been more slippery than literary criticism

has thought. In his "Rules ... for this time of Pestilentiall Contagion," physician Francis Hering writes, "Concourse of people to Stage-playes, Wakes or Feasts, and May-pole-dauncings, are to be prohibited by publique Authority, whereby as God is dishonored, the bodies of men and women by surfeiting, drunkennes, and other riots and excesses, disposed to infection, and the contagion dangerously scattered" (A4v). Hering's warning against the dangers of playgoing is not exclusively related to the presence of a disease factor among the audience, but rather in the theatre's capacity to expose its audiences to infection through overexcitement. Despite the fact that theatres were only open during times of low or no plague activity, we should consider the fear evoked by the words of the butler Jeremy (a.k.a. Face) in Ben Jonson's *The Alchemist*, that "the house, sir, has been visted"—indeed, that the house was in some sense always being visited, that the plague was a constant presence in early modern theatre (*The Alchemist* 5.2.4). Through its ability to emotionally excite its audience, and through the covert expression of the plague experience that I believe is part of the agenda of revenge tragedy, early modern theatre filters and represents this terrifying presence in the daily life of its audiences.

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# Plague's Messengers: Communicating Hope and Despair in England 1550-1750

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## Abstract

In our post September 11th society, we know that a letter has the power to kill, calling the nation to attention, but when one method of disseminating information breaks down, we can rely on many others. In plague-time England, however, the very stability of the nation might depend entirely on letters, and although no postal service existed for the average English citizen, the plague tampered with their mail on stages, in prose pamphlets, and in verse, revealing its power over their imaginations. After describing the most prominent scientific and religious theories linking letters with the spread of bubonic plague, I examine the plague letter as a device used by writers of the time (Dekker, Shakespeare, and Defoe among others) to display hope and despair through one of the most private modes of communication.

In this post September 11th society, we know all too well that a letter has the power to kill. A phone-call has the power to create hope or cause despair. An e-mail message can correctly communicate vital information or it can debilitate one's system with a virulent virus. A television program likewise can bring us important news that helps us improve our lives or it can reveal horrors on local, international, and even universal levels. But we are fortunate to have so many methods for communication; when one becomes tainted, we can rely on another. In times of terror or even of stress, we rely on multiple methods for sharing information.

In plague-time England, however, the stability of the nation sometimes depended entirely on letters, the only link between the king or queen and London. In his book *The Reign of Henry VIII: Politics, Policy and Piety*, Neil Sammon notes this phenomenon as he traces the erratic and extensive patterns of Henry VIII's early travels. Sammon concludes that disease, or rather Henry's fear of disease, was one of the biggest influences upon the court's itinerary: "In most years it was the plague which affected the court . . . [and] In less dramatic years the plague still continued to shape the king's itinerary...."<sup>1</sup> Henry's fear of disease left the entire court—and by extension the entire country—at the mercy of the plague. The plague kept Henry VIII away from his throne and on innumerable progresses in the country while Thomas Wolsey remained behind in London to make certain that the nation was running—via letters.

This seemed a reasonable method given the government's control over the post, which at that time in England's history was entirely a royal affair. Maintaining messengers and their horses and keeping them on time took enormous effort and money. Those who could afford to send their own messengers did so, but only the king or queen could establish carriers linked relay-style over great distances, ready to ride at a moment's notice. Due to expense and to the priority of royal mail, no one was allowed to send letters through the established carrier service without the authorization of the king or of the post master, and no public post existed until after the Restoration.<sup>2</sup> Whenever enemies threatened the nation, the restrictions on the mail increased and proved effective for confounding if not preventing rebel plots.

But perhaps running the affairs of the nation via letter was not a reasonable method as much as it was the only method. When plague threatened, the isolation of individuals became clearer, halting the post regularly and forcing kings and queens to wonder if they could trust the messenger. The plague did not need the permission of the king or the post master to send its own death threats, to tamper with the mail, or to taint its deliverer, and although there are no documented cases of a letter infecting its bearer or the recipient, the literature of the time confirms that death might make a letter its carrier. In fact, in plague-time the letter could deliver death by at least three distinct routes: by air, by imagination, and by curse.

In *The Wonderfull Yeare*, written in 1603, dramatist and pamphleteer Thomas Dekker notes the fear incited by a letter: "How many upon sight only of a Letter (sent from London) have started back, and durst have laid their salvation upon it, that the plague might be folded in that emptie paper, believing verily that the arme of Omnipotence could never reach them, unlesse it were with some weapon drawne out of the infected Citie."<sup>3</sup> London's plague traveled literally within the fibers of the letter, efficient in its ability to track down those who thought they could evade God's punishment by fleeing from the city. By letter, your own loved ones might unknowingly send death after you.

In plague-time, there was nowhere to hide when it seemed that all things—even the most intimate or the most practical—could become messengers of death. More than two decades later in 1625, John Taylor, a London waterman turned poet, confirmed this fear in his poem entitled "The Fearfull Summer or London's Calamity":

*Feare made nature, most unnaturall,  
Duty undutiful, or very small,  
No friendship or else cold and miserable  
And generally all uncharitable,  
Nor London letters little better sped  
They would not be received (much less read)  
But cast into the fire and burnt with speed  
As if they had been Hereticks indeed.*<sup>4</sup>

Perhaps if one could identify the letter early enough and burn it, the plague within would not take hold. Decades apart, Dekker and Taylor confirm the fear that plague might travel by attaching itself to a letter.

Such fears grew out of two inherited and, from a Renaissance perspective, tested systems of knowledge: one biblical, and one rooted in Galenic medicine. God could strike down in one blow whomever he wanted. He could do so in an instant, with one lightning strike—so why not with the letter? As Dekker suggests in the earlier passage, the letter might be a weapon wielded by the arm of Omnipotence. But although people believed that God was in every case the primary initiator of plague—initiating most often to punish sin—most also believed that God obeyed some rules of conduct. Specifically, God obeyed the rules of nature that he established himself. The natural causes of plague were then actually the secondary causes, through which God the prime mover worked. People could monitor those secondary causes to better protect themselves, and in order to gain the greatest control, they turned to the Renaissance authority—Galen.

Galenism, as we know, influenced the conception of disease for hundreds of years in western Europe. As a method for understanding the human condition with respect not to an afterlife but to nature, Galenism offered the very most scientific approach to medicine that was available, and all people from the university-trained physician to the housewife, dramatist, and servant girl, had at least a general understanding of its basic principles. For our purposes, it is enough to know that generally Galenic medicine observed the body as consisting of “naturals,” those things found naturally to compose the body, including the four humors. Directly affecting the naturals and coming from an external source were the non-naturals, which included air, exercise, food, drink, sleep, sex, and affections of the mind. Too much or too little of any of these non-naturals could bring about a change in the naturals, then give rise to things against nature, which were aptly called the contra-naturals and which included disease. The Galenic practitioner would attempt to eliminate the contra-natural by returning the naturals to their original state of balance through one of three methods: dietary regimen, herbal remedy, or surgery.

When it came to plague, Galen determined, and here the famed physician Ambrose Paré repeats in his *Treatise of the Plague*—this from the 1630 English translation—that “The generall and naturall causes of the Plague are absolutely two, that is, the infection of corrupt Aire, and a preparation and fitness of corrupt humours to take that infection” (4).<sup>5</sup> Once the non-natural, the air in this case, affected the naturals that were already imbalanced, the body would attempt to expel the extraneous and infected humors. Buboës, carbuncles, fever, and other signs indicated that the body was attempting to push out its excess.<sup>6</sup> All it took was an encounter between an ill-humored body and a pestilent vapor for the individual to die within days.

Pestilent vapors could stick to all bodies passing through them. For fear of such vapors, towns were often quarantined to prevent the stirring up or tracking in of the bad air, and during such unhealthy times, people suspected pestilent air of tampering not just with the mail but with all exchange of information, goods, and services. Even money thought to have been possessed by a plague victim was suspect, as Thomas Dekker and Daniel Defoe, among others, confirm. Dekker tells of men who would tie newly stolen coins into a bag at the end of a boat so that the water would wipe the plague sores off of the coins.<sup>7</sup> Over 100 years later H. F., the narrator in Daniel Defoe's *Journal of the Plague Year*, would explain at length how a citizen of London, fearful that plague had tainted a lost money bag, made efforts to purify the money before taking it:

In the middle of the yard lay a small leather purse with two keys hanging at it, with money in it, but nobody would meddle with it. I asked how long it had lain there; the man at the window said it had lain almost an hour, but that they had not meddled with it, because they did not know but the person who dropped it might come back to look for it. I had no such need of money, nor was the sum so big that I had any inclination to meddle with it, or to get the money at the hazard it might be attended with; so I seemed to go away, when the man who had opened the door said he would take it up, but so that if the right owner came for it he should be sure to have it. So he went in and fetched a pail of water and set it down hard by the purse, then went again and fetch some gunpowder, and cast a good deal of powder upon the purse, and then made a train from that which he had thrown loose upon the purse. The train reached about two yards. After this he goes in a third time and fetches out a pair of tongs red hot, and which he had prepared, I suppose, on purpose; and first setting fire to the train of powder, that singed the purse and also smoked the air sufficiently. But he was not content with that, but he then takes up the purse with the tongs, holding it so long till the tongs burnt through the purse, and then he shook the money out into the pail of water, so he carried it in. (87)

I enjoy this passage because it strikes me as a comical routine; yet, Defoe's narrator does not tell this in jest. He describes the scene in detail in order to depict the level of anxiety experienced by average citizens whenever they encountered an object—like a cloth coin purse—that might be tainted by plague. In any other time, that man would have snatched up the coin purse immediately so that no one would see, and instead he follows a labor-intensive and highly visible method of purification.

Vinegar sprinkles and lighter smokings were also recommended for purification of potentially infected goods, but these remedies could not work against the more vicious form of mail tainting that people feared during the Renaissance—that which originated in the imagination. It seems a cruel joke, but Renaissance men and women inherited the belief that emotions heightened in the imagination could make one more susceptible to

plague (or disease in general for that matter). Essentially this meant that if your family wrote from the city during plague-time to tell you that it seemed that the plague was abating and that all members of the house were well, the very sight of the letter might stir your humors and make you more likely to catch the plague. If on the other hand, you were residing in London and you received a letter that plague seemed to be spreading in your direction and that one of your dear friends in the country had died from it, your sorrow might also make you more likely to catch plague.

To help us understand this reasoning, it is worth returning to the Galenic understanding of plague's etiology: "the infection of corrupt Aire, and a preparation and fitness of corrupt humours to take that infection" were both necessary to produce symptoms of plague (4).<sup>8</sup> The vapors from corrupt air might stick on a letter and bring plague, but any number of things—from certain kinds of food to too much sex or lack of exercise and even heightened emotions—could corrupt the humors. In plague-time, even as early as 1348, doctors warned their patients of the danger of extreme emotion. Ambrose Paré explains here that,

Because Medicines come oft-times too late, and this Malady is as it were a sudden and a winged Messenger of our death, it commeth to pass that so many die thereof. And moreover because at the first suspition of this so dire and cruell a Disease, the imagination and mind (whose force in the diversly stirring up of the humours is great and almost incredible) is so troubled with feare of imminent death, and despaire of health, that together with the perturbed humors, all the strength and power of Nature falles and sinkes down. This you may perceive and know, by reason that the Keepers of such as are sicke, and the Bearers which are not fearfull, but verie confident, although they doe all [have] offices which may be for the sicke, are commonly not infected, and seldome dye thereof if infected. (34)

When a person feared the plague, his or her imagination immediately acted upon the humors, weakening them, while even those exposed to breath directly from a plague victim might remain in health provided the idea of plague did not scare them.

A letter from London might indeed be deadly if it spread toxic emotions. To sure up the humors, one should follow the doctors orders, as the most famous medical regimen of the time prescribes: "When Phisicke need, let these thy Doctors bee, Good dyet, quiet thoughts, heart mirthfull, free" (3).<sup>9</sup> But who could keep their thoughts quiet or their heart mirthful in plague-time? Some of the greatest literature of the period in Europe originated in part as recreation for the mind in troubled times, a way to prevent ailments by creating mirth. Boccaccio's *Decameron* is the first and best example but Ben Jonson's *The Alchemist* comes to mind.<sup>10</sup> These comic pieces, written in the midst of plague-time, bring with them a preventative for plague in the form of laughter, and just as a pleasing play or a joyful poem could make thoughts quiet or heart mirthful and

free, so too could the letter. This reasoning is of course quite like our current belief that stress can compromise the immune system, but what differs is the immediate and particular power of one bit of news or one piece of mail or one curse. We now instead see a host of things that weaken our systems, and while there may be "the straw that broke the camel's back," we do not believe that the content of a single message has the power to kill.

In the literature of plague-time, all it took was one message delivered one time. Daniel Defoe's account of the plague kiss clarifies this for us. H.F. explains how a man, "raving mad to be sure" and sick from the plague chased down a townswoman in the street:

When she see he wold overtake her, she turn'd, and gave him a Thrust so forcibly, he being but weak, and push'd him down backward: But very unhappily, she being so near, he caught hold of her, and pull'd her down also; and getting up first, master'd her, and kiss'd her; and which was worst of all, when he had done, told her he had the Plague, and why should not she have it as well as he. She was frighted enough before, being also young with Child; but when she heard him say, he had the Plague, she scream'd out and fell down in a Swoon, or in a Fit, which tho' she recover'd a little, yet kill'd her in a very few Days, and I never heard whether she had the Plague or no. (128)

H. F. concludes that this "poor unhappy Gentlewoman" was thereby "murther'd." Whether it was the fear of plague or the literal disease passed to her by the kiss that caused her death, Defoe's readers would see this as a death brought about by a single encounter. We do not hear that she was sinful or prone to worry or to illness. With one strike she falls.

Of course, just as a kiss more often pleases than maims, the messenger's delivery of a letter most often communicated hope and did indeed keep the country running. The recently popularized case of Galileo, who stayed in touch with his daughter by letter during time of plague, reveals the positive role that letters played. In 1633, Galileo's daughter, Maria Celeste, wrote to her father, explaining that although she had hoped to encourage him to visit her soon, she could not extend the offer after all but could only reach out to him via letter:

When I wrote to you, Sire, giving you an account of the contagion's spread in this region, it had already very nearly ceased . . . Wherefore, with this security, I moved to exhort you and implore you to return, although in my last letter, hearing that things were taking a turn for the worse, I held my tongue, so to speak. Because, although it is very true that I have a strong desire to see you again, what I want much more is the preservation of your health and safety; and I recognize the special grace of the Lord God in the opportunity you have had, Sire, to remain where you are much longer than you and I would have wished.

For even though I believe it must grieve you to stay on there so irresolutely, it would perhaps give you far more grief for us to be reunited among these perils, which in spite of everything continue on and may even be multiplying. (269)<sup>11</sup>

When it became dangerous to visit a loved one in person, the letter might travel instead, ideally keeping both parties intimately connected, healthy, and hopeful in a future reunion.

We can only imagine the fear, if not despair, brought about in plague-time whenever a letter was delayed. Of course, Shakespeare did this for us, when he wrote *Romeo and Juliet*—a play we all know so well that we take for granted the lines “A plague on both your houses.” We forget, however, that Mercutio utters this curse four times in a row. We remember that in many ways, Romeo and Juliet’s love has proven plague-like, contributing to their deaths when Romeo mistakes Juliet’s false suicide for true. We remember that the messenger who was supposed to deliver the letter explaining all of this to Romeo is unable to do so, but we forget exactly why because what matters to us more immediately is that the letter quite simply never makes it to its destination. But as Friar John, who was playing the messenger, explains to Friar Lawrence, it is worse than that:

Going to find a barefoot brother out,  
One of our order, to associate me,  
Here in this city visiting the sick,  
And finding him, the searchers of the town,  
Suspecting that we both were in a house  
Where the infectious pestilence did reign,  
[They] Seal’d up the doors, and would not let us forth;  
So that my speed to Mantua there was stay’d

.....

I could not send it;—here it is again—  
Nor get a messenger to bring it thee,  
So fearful were they of infection. (5.2.5-16)<sup>12</sup>

Friar John fails to deliver and, as his name confirms, Mercutio is a more successful messenger in this plague-time play than Friar John is. Mercutio’s repeated curse brings about a literal plague that tampers with the mail. The plague hand delivers Mercutio’s message while refusing to carry any others. The audience hears this message loud and clear: in plague-time, a letter can deliver death as easily as it can impart health. A plague on both your houses might arrive with the mail.

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6. For a discussion of contending medical theories on plague, see Walter Pagel's *Paracelsus: An Introduction to Philosophical Medicine in the Era of the Renaissance* (Basel, Switzerland: S. Karger, 1958), pp. 172-189, and Wade Oliver's *Stalkers of Pestilence: The Story of Man's Ideas of Infection* (Maryland: McGrath Publishing Company, 1970), pp. 49-123. Written in 1930, Wade's book is quite learned, covering theories on contagion with emphasis on plague from Hippocrates to Ehrlich, but its sound presentation is unfortunately
7. Dekker, p. 59, and see p. 3; For mention of plague-infected letters, see John Taylor, p. 15.
8. See note 5.
9. Regimen sanitatis Salerni: or, The schoole of Salernes regiment of health by Joannes, de Mediolano. 1634. For more on the two causes of plague, see Paré who comments on the particular susceptibility of military men who were infected at once: "there were manifest signes of corruption and putrefaction, in the Blood let the same day . . . from no other cause then an evill constitution of the Aire, and the Minds of the Souldiers perverted by Hate, Anger, and Fear" (9). Francis Bacon wrote in roughly the same decade that "As in infection and contagion from body to body (as the plague and the like) it is most certain that the infection is received (many times) by the body passive, but yet is by the strength and good disposition thereof repulsed and wrought out, before it be formed into a disease" (*Sylva Sylvarum* in *The Works of Francis Bacon*, ed. James Spedding, Robert L. Ellis, and Douglas D. Heath, 14 vols. [London: Longman, 1857-74; rpt New York: Garrett Press, 1968], 2.641).
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## NOTES

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## The Editor Comments

This double issue, dated fall/winter, 2003, allows us to bring the *Journal* back into schedule. We expect now to resume regular publication of four issues a year.

Because we are going to press in the first week of the new year 2004, it is appropriate to begin this issue with a look ahead. "Where Science is Headed—Sixteen Trends," by futurist Joe Coates, is based on his presentation to the Academy's annual reception, in November, for the presidents and delegates of our sixty affiliated societies (see list on inside back cover).

Research reports in this issue are in physics and philology, the former contributed by scientists from the Naval Surface Warfare Center in the Washington metropolitan area, the latter from a distinguished European university. Our science policy focus is represented here by a proposal for the diplomatic establishment of a "planetary defense regime" to alert nations to, and ultimately protect us against, the threat of collisions between Earth and objects in near-earth orbits, including asteroids, comets, and man-made debris. We invite readers to respond to this proposal with brief comments to be considered for publication. Finally, we continue our look to the history of science with a paper on botanical therapeutics in the centuries surrounding the settlement of the New World.

The Washington Academy of Sciences and its Affiliated Scientific Societies eagerly anticipate the Capital Science meeting to be held in March of 2004. Please join us there; you will find continually refreshed information about this event on our Web page, [www.washacadsci.org](http://www.washacadsci.org). And as always, readers are urged to submit papers to the journal by contacting the editor at [vcoates@concentric.net](mailto:vcoates@concentric.net) or [editors@washacadsci.org](mailto:editors@washacadsci.org).

Vary T. Coates



# Where Science is Headed—Sixteen Trends

Presented at the Meeting of the Affiliated Societies  
of the Washington Academy of Sciences  
November 18, 2003

Joseph F. Coates\*

While the scope of science is boundless, the contents massive, and the impact universal, it is still practical to see trends which mark the path of science into the future. Sixteen trends noted here are durable and likely to shape the overall scientific enterprise in the next decade or two. Trends within specific sciences are not covered.

1. *There is a continuing blurring of the distinction between science and technology.* This is most clearly seen in hi-tech areas such as the production of computer chips, where basic science is increasingly called upon for help and new capabilities are rapidly employed. More generally, science is called upon where the identifiable limitations of current technologies demand a fresh basic look to find radically new avenues of improvement. The classic example of this is the telephone industry's needs for relief from unrealistic future demands on equipment and on its workforce, which led to the invention of the transistor.

2. *The distinction between basic and applied science also continues to blur.* This is extremely significant because it implies the break up of the self-serving conceptual distinction made by academics. Obviously, academics prefer to see themselves as involved in basic scientific research, best characterized as self-initiated, with those in applied research assigned to a secondary and less prestigious status. In spite of all sorts of efforts to sustain the distinction, the differences between the two are fading quickly, in much the same way that the distinction between science and technology is fading. Practical needs and goals of the funders of research eventually shape, if not fully determine, the nature of the research enterprise. For example, Federal funders are increasingly requiring a statement of the potential future benefits of proposed research.

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In many advanced projects, best illustrated by the space program or by military technology, the need to achieve some objective such as "a man on the moon by the year X" implies that plans specify large numbers of developments that are not possible at the time the plan is written. This situation frequently leads to "research basic to...." This again is an illustration of the crack in the academic monopoly on basic research since many of these basic research projects end up in the hands not of universities but of non-profit and government laboratories and private contractors.

The two trends above link to a third trend in an important way because they show the shortcomings of the academic distinctions that are so important to maintaining the disciplinary categories at the university, and the associated performance necessary to progress up an academic ladder.

**3. *Interdisciplinarity is increasingly important in research while largely ignored by academics and their universities.*** Almost all of the new leading edge fields in science—genetics, brain research, and nanotechnology, as well as materials science, robotics and automation—require interdisciplinary R&D. The university is by and large not comfortable in accommodating this intrinsic demand of contemporary research. As a partial mechanism for dealing with the need for interdisciplinarity they often set up "institutes," which are more often than not only loosely linked to the basic science departments' teaching and curricula.

There clearly are exceptions to this common behavior. One can see, for example, several programs at Harvard, MIT and other distinguished universities getting into interdisciplinarity especially in their graduate schools. But as a rule the bulk of American universities' interdisciplinarity can be seen as aspiration or as empty claims rather than as reality. Far too often, academic programs attempt to achieve interdisciplinarity by the stapler rather than by the true conceptual integration of research programs and the production of something truly interdisciplinary.

Again, interdisciplinarity in science is more and more being captured by federal laboratories, by federal contractors, and by large non-profits such as SRI International. This is a pity, because first, it shortchanges the employers of the scientific workforce by training students too narrowly, in disciplines, while the action today is at the interface of disciplines. Second, it does the university a disservice by making it less viable as the primary or secondary place one wishes to go to in order to move into the most intellectually exciting research areas.

**4. *Credentialing in science is rapidly changing, expanding, and diversifying.*** This is a challenge to the traditional certifying by the university and is a response to the university's indifference and sluggishness in responding to new needs. The scientific enterprise is changing. Learning that is *ad hoc*, through free-standing courses or electronically-based colleges, certifications by professional societies, and

various other kinds of teaching and learning through the media, the Internet, and cassettes mark these forces for change. There is now also the credentialing beginning at high school that allows college credit for an expanding range of courses. There is the credentialing going on within corporations through in-house or contracted education and training programs for their own employees or contractors.

**5. *Globalization of both basic and applied research is rapidly progressing.*** This goes well beyond the two hundred-plus year globalization of science embodied in open literature exchange and international meetings. The current level of globalization involves the integration of research on global sites by research sponsors. Corporations such as Siemens or governmental agencies, looking for the highest degree of talent at the best possible cost, will buy that talent wherever it is.

Globalization has been facilitated by the end of the Cold War, which generated a super-abundance of cheap, highly skilled labor in the Iron Curtain countries, and by the more recent emergence of highly skilled labor in China, India, and to a lesser extent in other countries. The quality of that foreign talent is an attractive complement to the U.S. base, in being stronger in theory but perhaps marginal in goals and commitment to practical applications.

Aside from the low cost and high volume of talent available, information technology is the single most important facilitator of globalized research. It can, for example, give the research organization a 16- or even a 24-hour day in R&D, as research activity passes through time zone after time zone to make a global circuit. Round the clock research accelerates the productive outcomes of a project and thereby offers the sponsor a potential advantage in meeting competitive goals.

In addition, information technology allows extremely effective management by more or less wiping out distance as a temporal factor. With a little experience or training, both R&D managers and staff learn to communicate effectively and economically through the use of groupware and broadband communications to exchange and discuss real-time details—whether graphic, tabular, or simply verbal.

**6. *Outsourcing is increasingly commonplace.*** It is virtually universal in some sectors of research and development, production, test and evaluation. Field work is frequently outsourced. These tendencies are especially strong in the chemical sector and in information technology. In sectors with already extensive experience in outsourcing manufacturing, such as automotives, it is an easy and comfortable extension into outsourcing R&D. The key advantage is that it allows one to draw upon best available talent, while the cost is often lower and the flexibility much higher than if the work were conducted internal to the organization.

7. *English is now the universal language in science.* Scientists outside of the English speaking world strive to be published in English language journals. Young scientists—those under 40—are fully literate in English. The professional universality of English facilitates the globalization in outsourcing noted above. Possibly an exception to the universality is Japan. Technical and scientific results are often reported in both English and Japanese. But the difficulty of the Japanese language affords some advantage in which Japan can claim openness—and at the same time be relatively closed. This is accomplished by publishing many things, particularly in science policy, only in Japanese—and only much later, if at all in English. It is not clear the extent to which China is engaged in similar publication policies in the planned globalization of its own R&D.

8. *In the United States, basic and applied science is increasingly falling into the hands of foreign born scientists,* in training in American universities and among those already established in their field. This has to be good for the global community of science, for foreign countries, and for businesses outside of the United States, since we are the outstanding training ground for scientists in almost every field. The policy issue needing to be examined is whether this growing dependency on foreign-born talent is good for the future of the U. S. R&D establishment and for our general competitive position in the world. Heartfelt beliefs are no substitute for the absent research on this issue.

Recently a new issue has arisen that has not been adequately documented in terms of scope and significance. It appears to be quite common that a hi-tech firm, usually an information technology firm, will fire high priced native-born scientists and then make a plea to import foreign scientists at a substantially lower pay rate to fit a gap in its work force. While that is the overall pattern, the details by which one can accomplish this are complex. This illustrates a side effect of globalization of talent, and it creates a domestic issue. What are the effects on the economic health and well-being of individual American scientists, engineers, and technologists, and on their families? Should companies be allowed openly or by subterfuge to replace a citizen by a foreigner merely to enhance the corporate bottom line?

9. *Physical science is still king of the hill, although biological sciences are fast coming to share that primacy, especially through genetics research, medical research, and brain research.* The area where the most definitive research is conducted and hence the largest economic value continues to lie is in physical science and its derivative applications. My criterion for the status of the sciences is their ability to make definitive, unequivocal, highly reliable, and precise responses to current needs and questions through practical applications. There is no doubt that almost any questions of a mechanical, engineering, material or electronic sort can be

answered definitely so that one can confidently make institutional, operational, planning and personal decisions.

The social sciences are still at the pre-definitive stage; that is, both theory and research often—if not usually—fall short of definite conclusions to shape policy, planning, and actions. They however should not be dismissed in public organizational decision making. They are able to inject an awareness of incompleteness, uncertainty, and openness into plans, programs, and projects that scientists, engineers, business people, and politicians may be too aggressively promoting. On the other hand, the social sciences, because they are still at a pre-definitive stage, too often have a strong ideological orientation and a less-than-even-handed approach to social, economic and political issues. Regrettably, the social sciences in their relentless move toward more and more quantitative methods (apparently in some mimicry of physical sciences) have all too often given theory short shrift.

10. *Physical and biological sciences are undergoing increasingly important changes because of effects of information technology, particularly computers and telecommunications.* Devices, equipment, tests, and analyses are moving to smaller and smaller scale, with the consequence that often incredibly large numbers of analyses and vast amounts of data are produced rapidly. Particularly in pharmacology, chemistry, and genetics, thousands of tests can routinely be conducted simultaneously on small scale arrays. An interesting example of the practical effects is in forensic science, where incredibly small amounts of DNA evidence can provide definitive identification in a criminal situation.

Secondly—apparently at odds with the above—is that low cost tools, equipment, and techniques now offer much broader opportunities for field work. For example, low cost sensors and reporting devices can be put out in large numbers to collect a volume of information that was unthinkable difficult to gather twenty years ago. Sensors are now often in practice and surely in principle able to detect anything that one would want to detect. One sees this, for example, in the development of artificial noses to detect contraband material. Any physical phenomenon or biological material or other signal such as precursors to earthquakes can now be sensed or measured and hence contribute to the overall competence of the sciences in practical affairs and theoretical understanding.

Thirdly, simulation has become a tool in virtually every scientific area. Soon nothing will be constructed until it has been planned, designed, tested, evaluated, and modified in cyberspace.

11. *Ecology is the logical scientific base for all environmentalism and for the environmental movement.* But regrettably progress is slow, underfunded, and without a sound theoretical base. One only has very general semi-quantitative and

qualitative notions, such as “everything goes somewhere” serving as weak theory. Without an adequate scientific base we still see a tremendous amount of gratuitous conflict and disagreement with regard to environmental management and the future.

**12. *The scientific knowledge held by the public is pitifully thin and unreliable.***

Recurrent surveys sponsored by the National Science Foundation show the ubiquity of ignorance about science. The government is the primary potential source of remedy for this deficiency. But both the executive and legislative branches more or less sit on their hands. The National Science Foundation had its political misadventure decades ago in producing text book material and has been gun shy ever since. The most conservative inhabitants of Capitol Hill are ever ready to block educational, medical, or other information they find ideologically obscene, and to punish the perpetrators by budgetary cuts or constrictive legislation. The President's education program promises “no student left behind” but at least as far as science goes, it is a joke.

The primary consequence of this regrettable state of public ignorance is that as more and more often scientific matters become public policy issues, the population is left open to extremist, erroneous or fantastic claims, unsound policy solutions, and a general intellectual mess of conflicting and faulty recommendations and ultimately bad laws, regulations and policies.

**13. *Industrial sponsored basic research has more or less tanked.*** It is difficult to see much basic research with a truly long term perspective, or beyond their immediate business interests in the 25 or so top firms in terms of R&D investment. The amount of money industry spends on research is not strongly correlated with its basic nature. General Motors and Ford are among the nation's, and therefore the world's, largest funders of R&D. They have been right up there for decades, and yet can the reader name even one distinguished American scientist employed by either company, much less a Nobel laureate?

**14. *Hobbyists, ideologues and amateurs are challenging traditional science in two separate ways.*** Many are literally challenging the reliability of research coming out of the established scientific community. This is clearly illustrated in the health and medical area. One has only to turn to the Internet to be confounded by the tremendous lot of truths, half-truths, lies, falsifications, and misunderstandings to be found there on any health issue. The Internet also widely propagates the occult and semi-occult. Many people still believe that something special went on at Roswell, many people believe that there are extraterrestrials visiting us – and kidnapping some of us. Others still doubt that man has walked on the moon.

On the other hand, the development from hobbyist into an amateur scientist brings us all benefits. Now it is possible for thousands of people with surplus time on their computers to link into large scale scientific experiments to do data processing, gratis, as public service. Repeatedly, amateurs are making astronomical discoveries of substantial importance.

The scientific community needs to develop better ways of coping with the ideologues and the ignoramuses and at the same time promoting scientific hobbyists and talented amateurs.

15. *There is growing tension from the strong pressure for useful results—on schedule—in government, business and foundation funding of R&D.* The commitment to the bottom line in business is what underlies the pressure for scheduling what usually cannot be scheduled. It is not quite so clear what the driver for “results on demand” is in government funding agencies. The net effect is to drive out attention to what is and which must be uncertain in its outcome and timing. Science is now becoming a victim of a concept made famous in a different domain by Henry Kissinger: “The urgent drives out the important.”

16. *There is a continuing call for technology assessment, but not under that name.* The Congressional Office of Technology Assessment, after a quarter of a century of distinguished service to Congress and therefore to the nation was deep-sixed by a group of aggressive conservatives new to the Congress and not understanding how it worked or what support it needed. Technology assessment is not now conducted anywhere in the United States, but the cry for it comes up in many corners, including Capitol Hill. A recent example is Bill Joy’s plea for better understanding of the future consequences of self-reproducing and intelligent robotics, genetics, and nano devices. His near-frantic plea for understanding showed that he was unfamiliar with the concept of technology assessment and what can be done and what had been done, but the plea is nevertheless justified. While the concept of TA is thriving in Europe and growing elsewhere in the industrialized nations, we who have the largest economy and the largest commitment to R&D and to the ubiquitous use of technology see our political and business leadership remaining staunchly indifferent to anticipating what side effects and unanticipated outcomes could be.

## Conclusion

These notes on trends shaping the future of science do not cover the rich texture of forces more specifically shaping the individual sciences, nor do they probe the manifold pressures on public and private science policy. Nevertheless they offers a framework for policy discussion and a pattern into which more detailed forces and factors can be integrated.

# Measurement and Analysis of the Permittivity and Permeability of Siloxane Containing Metal Helices

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## Abstract

Measurements have been carried out by us on materials consisting of a non-conducting matrix such as epoxy that contained randomly oriented metal microhelices, in view of the apparently superior radar absorption properties of these chiral mixtures. In the present study we employ helices with parallel orientations imbedded in siloxane, and measure permittivity  $\epsilon$  and permeability  $\mu$  of the effective chiral materials as a function of frequency. As a novel feature beyond the previous measurements, we here observe two resonances simultaneously in some of our measurements. These are analyzed using the single-scattering theory of Bohren et al.

## Introduction

Optical activity of naturally active substances, such as sugars, has been a topic of investigation from the nineteenth century onward. The study of corresponding effects for microwaves was first undertaken by Lindman (1920; 1922) in 1920, employing microwaves of 12-35 cm wavelength incident on 2-300 randomly oriented, 9 cm long copper wires wound 2-1/2 times in the form of a helix of 10mm diameter. His observation of a rotation of the polarization plane agreed with dispersion formulas given by Drude (1900) for the case of optical activity. Subsequent microwave experiments were done by Tinoco et al. (1957; 1960) on oriented arrays of 1 cm long, 0.5 cm diameter copper wire helices (3 turns, 4.7 cm wire length) in polystyrene. Again the measurements demonstrated the optical rotation (including the Cotton effect) caused by the helices, and were interpreted by a three-term Drude formula.

More recently, prompted by the notion of enhanced radar absorptivity of chiral materials (Jaggard et al., 1979; Varadan et al., 1987; Jaggard and Engheta, 1989; Varadan and Varadan, 1990), a number of experiments using miniature randomly

oriented metal helices imbedded in low-loss dielectric materials such as epoxy to form a composite chiral material, were carried out at Pennsylvania State University (Guire et al. 1990; Umari et al., 1991; Ro et al., 1992; Hollinger et al. 1992), in Toulouse, France (Priou, 1989; Priou and Roques, 1991), and elsewhere (Timmerman et al. 1991; see also Kong, 1991). The media were characterized by free-space microwave measurements, or by measurements in a wave guide (Hollinger et al., 1992). Predominantly, determinations were made of the microwave rotatory dispersion (optical activity), the transformation of planar to elliptical polarization (optical dichroism), and the helicity parameter  $\beta$  of the composite medium; some references also measured the power absorption (or reflection) coefficient of the microwaves (Priou, 1989; Guire et al., 1990; Ro et al., 1992) which showed a broad spectral resonance at approximately 12-15 GHz over a frequency region of about 10 GHz up to 20 GHz or more. Subsequently, there have been several attempts at analyzing some of the experiments (Bohren et al., 1992; Bahr and Clausing, 1994; Luebbers et al., 1995), sometimes casting doubt on the helicity dependence of this absorption. Measurements of the effective permittivity  $\epsilon$  and permeability  $\mu$  of the composite material are mentioned only by Priou (1989) and by Timmerman et al., (1991).

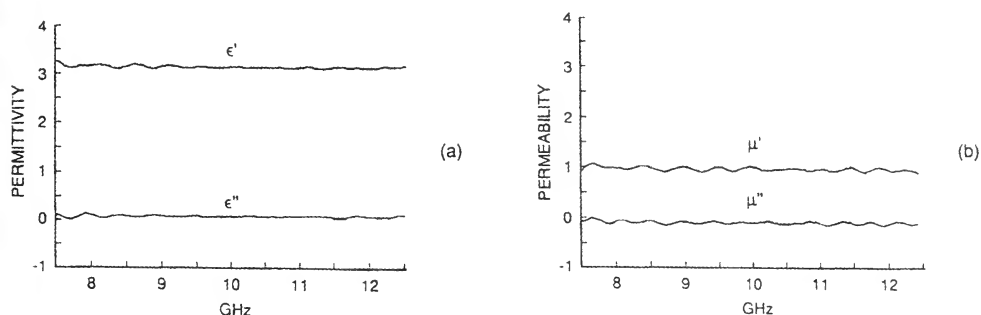
In the present study, a measurement of  $\epsilon$  and  $\mu$  has been carried out for a composite medium consisting of parallel-oriented miniature copper helices (of 2 or 4 turns) imbedded in a siloxane matrix, in the frequency region 7.5 – 12.5 GHz. For the 2-turn helices, two resonances were found in  $\epsilon$  and in  $\mu$  in this frequency region. This is the first case known to us of more than one resonance being present in a modern measurement of a chiral composite, the only other (older) case appearing in Tinoco and Freeman's (1957) experiment which refers to just the optical activity of macroscopic helices imbedded in polystyrene, i.e. essentially in free space. Using Bohren et al's (1992) single-scattering theory we analyze our experimental results at the resonance frequencies, thereby obtaining a fairly close agreement with the measured data.

## Experiment

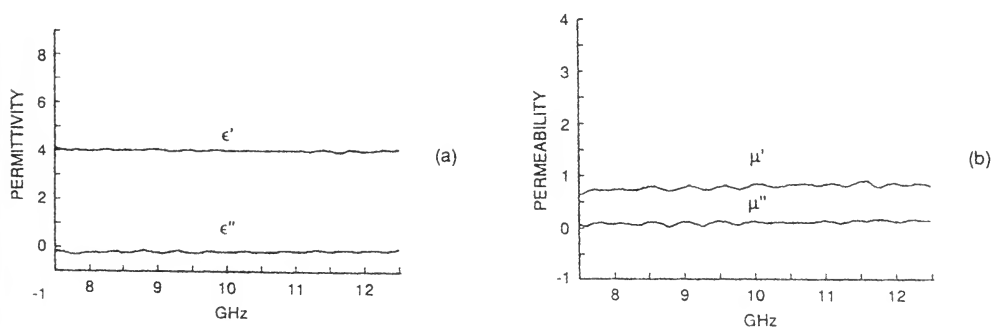
The siloxane samples prepared for our experiment were of dimension 22mm by 10mm, and of varying thickness of the order of 2mm. Two types of copper-wire (diameter 0.019 cm) miniature helices were imbedded in their entirety in some of the samples: (a) two-turn helices of wire length  $\lambda = 11$ mm, helix diameter 1.75mm, pitch angle  $7^\circ$ , and helix length 1.35 mm, and (b) four-turn helices of wire length  $\lambda = 16$ mm, diameter 1.25 mm, pitch angle  $8^\circ$ , and helix length 2.2mm. About 20 helices were imbedded in each sample (3% by volume), with axes parallel to each other and normal to the sample surface, in two different ways, namely: (i) all helices were left-handed, and (ii) half of the helices were left handed and half right-handed,

the sample then being a racemic mixture. These samples were inserted flush across the width of the rectangular (22 x 10mm) waveguide attachment of a Hewlett-Packard 8510 network analyzer which was equipped with software for providing real and imaginary values for  $\epsilon$  and  $\mu$ , as a function of frequency in the 7.5-12.5 GHz range.

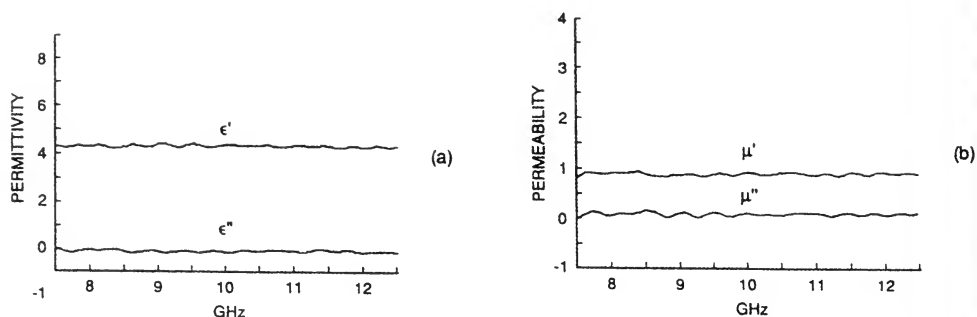
Figure 1 shows the real and the imaginary parts of  $\epsilon$  and  $\mu$  for an empty siloxane matrix of 1.65mm thickness. No visible dispersion is apparent. In Figure 2, we see the same quantities for a racemically (two-turn helices) loaded matrix of 1.55mm thickness. No effect of helicity is observed, the small increase of  $\epsilon'$  (to 4.0) being attributable to the mere presence of the 3%- volume metal loading in the siloxane. Exactly the same is true for four-turn helices racemically imbedded in 2.25mm thick siloxane, Figure 3.



**Figure 1.** (a) Real and imaginary parts of  $\epsilon$  vs. frequency for a 1.65mm unloaded siloxane matrix. (b) Same for  $\mu$ .

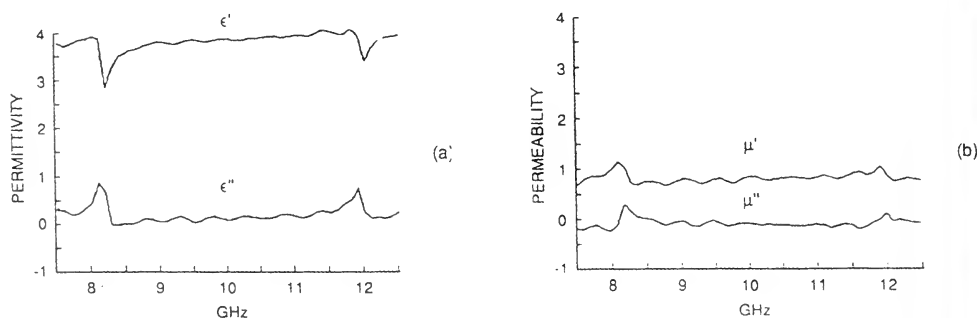


**Figure 2.** (a) Real and imaginary parts of  $\epsilon$  vs. frequency for a racemic mixture of 3% by volume two-turn copper-wire helices imbedded in a 1.55mm thick siloxane matrix. (b) Same for  $\mu$ .

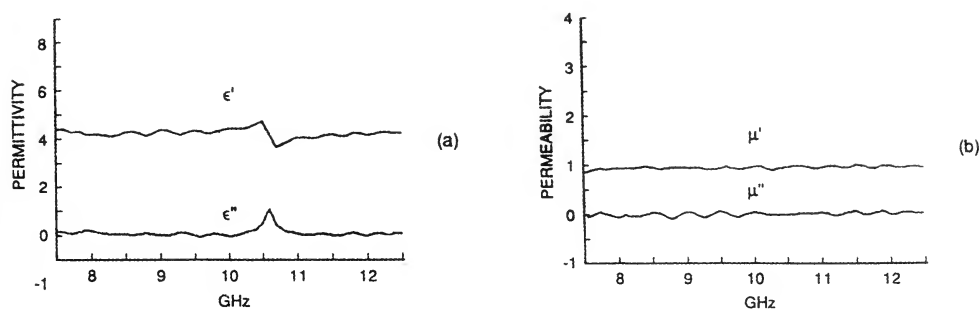


**Figure 3.** (a) Real and imaginary parts of  $\epsilon$  vs. frequency for a racemic mixture of 3% by volume four-turn copper-wire helices imbedded in a 2.25mm thick siloxane matrix. (b) Same for  $\mu$ .

Helicity effects are, however, strongly apparent in Figure 4, corresponding to two-turn left-handed helices imbedded in a 1.35mm thick siloxane matrix, as well as in Figure 5 corresponding to four-turn left-handed helices in a 2.45mm thick siloxane matrix. In Figure 4, two resonances are apparent for the two-turn helices, at  $f_1 = 8.066$  GHz and at  $f_2 = 11.888$  GHz, for  $\epsilon'$  interfering destructively with the  $\epsilon'_b = 4.0$  background value between the resonances, and for  $\epsilon''$  rising above the  $\epsilon''_b = 0.0$  null-background value. This is also the case for  $\mu''$  (null background value  $\mu''_b$ ), while the  $\mu'$  resonances interfere constructively with the  $\mu'_b = 1.0$  background value. It is remarkable that the presence of metal helices engenders these magnetic effective properties of a sample where siloxane is a naturally non-magnetic medium.



**Figure 4.** (a) Real and imaginary parts of  $\epsilon$  vs. frequency for 3% by volume two-turn left-handed copper-wire helices imbedded in a 1.35mm thick siloxane matrix. (b) Same for  $\mu$ .



**Figure 5.** (a) Real and imaginary parts of  $\epsilon$  vs. frequency for 3% by volume four-turn left-handed copper-wire helices imbedded in a 2.45mm thick siloxane matrix. (b) Same as for  $\mu$ .

In Figure 5, only one resonance appears for the four-turn helices at  $f_3 = 10.558$  GHz, for  $\epsilon'$  interfering with the  $\epsilon_b' = 4.0$  background at an intermediate phase angle (different from  $180^\circ$ ) and for  $\epsilon''$  rising above the  $\epsilon_b'' = 0.0$  null-background. No such resonance is visible in either  $\mu'$  or  $\mu''$ ; this fact is not understood, since a resonance might well have been expected.

## Analysis

We first consider the data of Figure 4(a) and (b) that present, respectively, the measured values of the permittivity  $\epsilon \equiv \epsilon' + i\epsilon''$  (separately for  $\epsilon'$  and for  $\epsilon''$ ) and of the permeability  $\mu \equiv \mu' + i\mu''$  (separately for  $\mu'$  and for  $\mu''$ ) of our samples containing two-turn helices, measured over the frequency range of 7.5 GHz to 12.5 GHz. Two resonances appear in each of the four mentioned quantities, the lower one located at  $f_1 = 8.066$  GHz and the upper one at  $f_2 = 11.888$  GHz. Away from these resonances values, the data are, within experimental accuracy, compatible with a background value of  $\epsilon_b = 4.0 + 0i$  and  $\mu = 1.0 + 0i$  which is also close to the measured data for the siloxane matrix alone (Figure 1), (variations from  $\epsilon_b$  arising from the lack of metal content of the matrix), and especially to those for siloxane containing racemic mixtures of helices, both two-turn (Figure 2) and four-turn (Figure 3). This indicates that siloxane with imbedded helices may be considered an effective medium, whose effective values of  $\epsilon$  and  $\mu$  will, outside the resonances, be taken here as having the background values  $\epsilon_b = 4.0 + 0i$  and  $\mu_b = 1.0 + 0i$ .

At the resonances themselves, Figure 4 for the two-turn helices provides the values shown in Table 1 for  $\epsilon$  and  $\mu$ . Since subsequently the product  $\epsilon\mu$  will be considered, Table 1 lists the resonance values for this quantity also. Our analysis of the resonance values follows the single-scattering theory of Bohren et al. (1992), which was first developed for non-helical scatterers as quoted by Bohren and Huffman (1983), and then adapted for helical scatterers by Bohren et al. (1992). In this latter analysis, electromagnetic waves traversing a slab that contains more or less uni-

formly distributed chiral inclusions (of number  $N$  per unit volume) are shown to propagate only in the form of right (R) or left (L) circularly polarized components with effective wave numbers

$$k_{L,R} = k[1 + i(2\pi N/k^3) \langle x \rangle \pm (2\pi N/k^3) \langle y \rangle] \quad (1)$$

where  $k$  is the incident wave number in the ambient medium,

$$\langle x \rangle = (\mathbf{X} \cdot \hat{\mathbf{e}}_x)_{\theta=0} \quad (2a)$$

$$\langle y \rangle = (\mathbf{Y} \cdot \hat{\mathbf{e}}_y)_{\theta=0} \quad (2b)$$

$\hat{\mathbf{e}}_x$  and  $\hat{\mathbf{e}}_y$  being orthonormal vectors orthogonal to the incident wave, and  $\mathbf{X}$  is the vector scattering amplitude for a single inclusion illuminated by a wave polarized along  $\hat{\mathbf{e}}_x$  with  $\theta = 0$  the forward scattering angle. Equation (1) is correct not only for the case of randomly oriented chiral inclusions for which it was used by Bohren et al. (1992), but for the case of any chirality orientation, as our repetition of the derivation of this equation (Bohren et al., 1992; 1983) has shown. It is valid for a sufficiently dilute suspension, and for particle sizes small compared with the wavelength. It should be noted that the definition for right or left circular polarization is here taken as the "optical" one (Jackson, 1975), i.e. the wave with polarization vector  $\hat{\mathbf{e}}_x + i\hat{\mathbf{e}}_y$  is left, and with  $\hat{\mathbf{e}}_x - i\hat{\mathbf{e}}_y$  is right circularly polarized.

Table 1. Measured Resonances Values of  $f_n$ ,  $\epsilon$  and  $\mu$  for 2-Turn Helices, and Quantities Based Thereupon.

$f^{(res)}$	$f_1 = 8.066 \text{ GHz}$	$f_2 = 11.888 \text{ GHz}$
$\epsilon$	$2.8 + 0.9i$	$3.3 + 0.8i$
$\mu$	$1.2 + 0.3i$	$1.2 + 0.2i$
$\epsilon\mu$	$3.09 + 1.92i$	$3.80 + 1.62i$
$\text{Re}(\epsilon\mu)^{1/2}$	1.83	1.99
$c_{eff}^{(res)}$	$1.64 \times 10^{10} \text{ cm/s}$	$1.51 \times 10^{10} \text{ cm/s}$
$\lambda^{(res)}$	2.03 cm	1.27 cm

Maxwell's equations are generalized for a chiral medium to read (Varadan et al., 1987; Bohren et al., 1992):

$$\mathbf{D} = \epsilon \mathbf{E} + \epsilon \beta \nabla \times \mathbf{B} = \mu \mathbf{H} + \mu \beta \nabla \times \mathbf{H} \quad (3)$$

in which, besides  $\epsilon$  and  $\mu$ , a third parameter  $\beta$  (chirality parameter) is present. Plane harmonic solutions of these equations propagate as left- or right-circularly polarized waves with wave number

$$k_{L,R} = \omega(\epsilon\mu)^{1/2} / [1 \mp \beta\omega(\epsilon\mu)^{1/2}] \quad (4a)$$

$\omega$  being the circular frequency; the chirality parameter is thus:

$$\beta = \frac{1}{2} (k_R^{-1} - k_L^{-1}). \quad (4b)$$

Furthermore,  $\sqrt{\epsilon\mu}$  can be related to  $k_{L,R}$  as follows. For sufficiently dilute suspensions for which Equation (1) is valid, this equation may be exponentiated to read:

$$k_{L,R} = k e^{\gamma(i\langle x \rangle \pm \langle y \rangle)} \quad (5a)$$

where

$$\gamma = 2\pi N/k^3 \quad (5b)$$

Equation (4) then leads to

$$(\epsilon\mu)_{\text{eff}} = (\epsilon\mu)_b \exp(2i\gamma\langle x \rangle) / \cosh^2 \gamma\langle y \rangle, \quad (6a)$$

$$\beta = k^{-1} \exp(-i\gamma\langle x \rangle) \sinh \gamma\langle y \rangle. \quad (6b)$$

Next, we shall evaluate the scattering amplitudes  $\langle x \rangle$  and  $\langle y \rangle$  for a metal helix of high conductivity.

Formulas for these scattering amplitudes for straight conducting wires, at the resonance amplitudes, were obtained by Cross (1969) as quoted by Peebles (1984). Our approach will consist in shaping this wire into a helix, and integrating the scattering amplitude over the helix. It was shown by Lindman (1920) and Tinoco and Freeman (1957) that the resonance frequencies are determined by the length of the wire  $\ell$ : The fundamental resonance corresponds to a standing wave of half a wavelength spanning the length of the wire in the helix, the first overtone to a full wavelength, the second to one and a half wavelengths, and so forth. These waves on wires are known as "traveling waves" while propagating (Guo and Überall, 1994), and when back-reflected by the wire ends to form standing waves as mentioned, resonances ensue. Our analysis will be based on this picture.

Accordingly, we obtain the wavelengths of the standing waves along the wire in the helix  $\lambda_1$  or  $\lambda_2$ , at the two measured resonance frequencies  $f_1$  and  $f_2$ , respectively (Table 1), from the formula

$$\lambda_{1,2} = c_{\text{eff}}^{(1,2)} / f_{1,2} \quad (7a)$$

where the effective traveling-wave phase speeds  $c_{\text{eff}}^{(1,2)}$ , to be calculated at the resonances, are given by

$$c_{\text{eff}} = c / \text{Re}(\epsilon\mu)^{1/2} \quad (7b)$$

with  $\text{Re}$  denoting the real part, and  $c$  the free-space light velocity  $= 3 \times 10^{10}$  cm/s. The latter are entered in Table 1, as well as the resonance values  $\lambda_{1,2}$ . From these follows:

$$\lambda_1/\ell = 1.85 \cong 2 \quad (8a)$$

$$\lambda_2/\ell = 1.15 \cong 1, \quad (8b)$$

showing that the first resonance constitutes the fundamental standing-wave resonance along the wire, and the second one constitutes the first overtone.

The minor deviations from exact integers in Equations (8) are also evident in the optical-rotation analysis of Tinoco and Freeman (1957), as well as in the analysis of the power absorption coefficient of Ro et al. (1992). In the latter reference, the ratio of  $L/\lambda^{(\text{res})}$  at the there-observed resonance was determined as

$$L/\lambda^{(\text{res})} = 0.6037 \cong 1/2 \quad (9a)$$

but where  $L$  was defined as the wirelength per turn of the helix. Since three-turn helices were used, one has  $\ell = 3L$  and Equation (9a) identifies the resonance observed by Ro et al. (1992) as the second overtone,

$$\ell \cong (3/2)\lambda^{(\text{res})}, \quad (9b)$$

of the standing-wave resonances of this helix. Our reasoning indicates that  $\lambda/\ell$  is the physical quantity identifying the character of the resonances, rather than  $\lambda/L$  taken over one turn of the helix, as was done by Ro et al. (1992). This latter quantity has no direct physical meaning, nor does it constitute a universal parameter for the design of microwave chiral absorbers since it depends on the overtone character of the resonance under consideration.

The scattering amplitudes for a straight wire ("dipole") of length  $\ell$  are quoted by Peebles (1984) as

$$\begin{aligned} \langle x \rangle_{\text{dipole}} = (\eta/\pi Y) \cos^2 \theta_d \{ [\cos(\pi \ell \lambda^{-1} \sin \theta_d \sin \Phi_d) - \cos(\pi \ell \lambda^{-1})]^2 \\ * [1 - \sin^2 \theta_d \sin^2 \Phi_d]^{-2} \} \end{aligned} \quad (10a)$$

$$\begin{aligned} \langle y \rangle_{\text{dipole}} = (\eta/\pi Y) \cos \theta_d \sin \theta_d \cos \Phi_d \{ [\cos(\pi \ell \lambda^{-1} \sin \theta_d \sin \Phi_d) - \cos(\pi \ell \lambda^{-1})]^2 \\ * [1 - \sin^2 \theta_d \sin^2 \Phi_d]^{-2} \} \end{aligned} \quad (10b)$$

where the dipole orientation is  $(\theta_d \Phi_d)$ , and the coefficients are given as  $\eta = 120\pi \Omega$ , and for the first three resonances, the value of the constant  $Y$  is (Peebles, 1984):

$$(\pi \ell / \lambda)_1 = \pi/2, Y_1 = 73.0\Omega \quad (11a)$$

$$(\pi \ell / \lambda)_2 = \pi, Y_2 = 224.6\Omega \quad (11b)$$

$$(\pi \ell / \lambda)_3 = 3\pi/2, Y_3 = 105.4\Omega \quad (11c)$$

Of these, the quantity  $Y_2$  was not determined a-priori by Peebles (1984), but by an empirical fit to a model-dependent calculation. Since this value in Equation (11b) does not present a logical sequence in Equation (11), we prefer to adopt below the average between  $Y_1$  and  $Y_3$ , namely

$$Y_2 = 89.2 \Omega \quad (11d)$$

which leads to reasonable results in our subsequent analysis.

Working at the resonance frequencies of our helices, we obtain the helix-values of Equation (10) by integrating over the helix shapes (the helix axis being the  $z$  direction),

$$\langle x \rangle_{\text{helix}} = (\tilde{N}\eta/\pi Y_n) \int_0^{2\pi} d\Phi_d \sin^2\theta \left\{ [\cos(\pi\ell\lambda^{-1} \cos\theta \sin \Phi_d) - \cos(\pi\ell\lambda^{-1})]^2 \right. \\ \left. * [1 - \cos^2\theta \sin^2\Phi_d]^{-2} \right\} \quad (12a)$$

$$\langle y \rangle_{\text{helix}} = (\tilde{N}\eta/\pi Y_n) \int_0^{2\pi} d\Phi_d \sin\theta \cos\theta \cos\Phi_d * \left\{ [\cos(\pi\ell\lambda^{-1} \cos\theta \sin\Phi_d) - \cos(\pi\ell\lambda^{-1})]^2 \right. \\ \left. * [1 - \cos^2\theta \sin^2\Phi_d]^{-2} \right\} \quad (12b)$$

where  $\tilde{N}$  is the number of turns of the helix,  $\theta$  its pitch angle,  $n$  indicates the overtone number of the resonance under consideration,

$$\ell = 2\pi\tilde{N}a/\cos\theta \quad (13a)$$

the length of the wire in the helix,  $a$  the helical cylinder radius, and we also have

$$\tan\theta = h/2\pi\tilde{N}a \quad (13b)$$

where  $h$  is the helical cylinder length.

The integrals in Equation (12) have been evaluated numerically for the two resonances of our two-turn helices given in Table 1. Table 2 lists the calculated values of the quantities indicated; the values of  $\gamma$ , Equation (5b), are based on a density of inclusions  $N = 38.2 \text{ cm}^{-3}$ . The calculated values of  $\epsilon\mu$  follow from Equation (6a). These agree reasonably well with the experimental values of  $\epsilon\mu$  shown in Table 1. It is noted that the calculated resonance values of  $\langle y \rangle$  are zero; Equation (6b) then shows that the resonance values of  $\beta_{\text{eff}}$  vanish. This is in agreement with the chirality parameter, as a function of frequency, undergoing a zero crossing at the resonance (Bahr and Clausing, 1994).

Table 2. Calculated Resonance Values for 2-Turn Helices.

$f^{(\text{res})}$	$f_1 = 8.066 \text{ GHz}$	$f_2 = 11.888 \text{ GHz}$
$\gamma$	6.225	1.944
$\langle x \rangle$	0.0390	0.0523
$\langle y \rangle$	0	0
$2\lambda\langle x \rangle$	0.485	0.203
$\epsilon\mu$	$3.5 + 1.9i$	$3.9 + 0.9i$

For our four-turn helices, the resonance appearing in  $\epsilon$ , Figure 5(a), at the frequency 10.558 GHz can be identified as a second-overtone resonance. The absence of a corresponding resonance in  $\mu$ , Figure 5(b), is not understood (although a reso-

nance would have been expected) and therefore, no analysis as in the foregoing has been attempted for this case.

As a final note, the absence of any resonance effects apparent in the racemic mixtures, Figs. 2 and 3, can be explained from our analysis also. We have already seen that  $\langle y \rangle = 0$  at the resonance frequency; this leads, from Equation (4), to  $k_L = k_R$  and  $\beta = 0$  at the resonance itself, but not outside the resonances (Bahr and Clausing, 1994). However, the integration in our Equation (12) is such that if an equal number of right-handed and left-handed helices are present, i.e., the integration is taken as one-half  $(0, 2\pi)$  and one-half  $(0, -2\pi)$ , not only  $\langle y \rangle = 0$ , leading to  $k_L = k_R$  and  $\beta = 0$  (no effective chirality present), but also  $\langle x \rangle = 0$ , so that from Equation (6) we also have  $(\epsilon\mu)_{\text{eff}} = (\epsilon\mu)_b$ , leading to the absence of resonances. The same argument can also be shown to hold if the helices are not oriented along the  $z$  direction, but, e.g., have random orientations.

## Conclusions

In the present experiment, measuring the values of  $\epsilon$  and  $\mu$  in samples of parallel copper helices (both left-handed or racemic) imbedded in siloxane as a function of frequency in the 7.5 – 12.5 GHz region, two resonances were observed in the two-turn-helix sample and one resonance in the four-turn sample. Except for two resonances having been seen in the free-space measurements of the optical activity by Tinoco and Freeman (1957), this is the first case of more than one resonance appearing in a modern helicity experiment.

Based on the arguments of Lindman (1920) and Tinoco and Freeman (1957), these physical explanations of the resonances have been provided here as being due to standing waves (Guo and Überall, 1994) set up along the overall length  $\ell$  of the helical wire, the resonance orders corresponding to a fundamental standing wave of one-half wavelength spanning  $\ell$ , and the overtones to 1, 3/2, 2, 5/2... wavelengths spanning  $\ell$ . In this way, our two 2-turn-helix resonances were identified as the fundamental and first overtone, our single 4-turn-helix resonance as the second overtone, and the resonances of Bahr and Clausing (1994) as a fundamental, and of Ro, Varadan and Varadan (1992) as a second overtone again.

The arguments and numerical illustrations of Bohren et al. (1992) seem to indicate a relative insensitivity of reflection or absorption coefficients of the chiral sample to the actual degree of helicity of the inclusions, provided only that the overall length of the wires  $\ell$  is kept the same. However, the volume concentrations of the helical inclusions do have a strong influence on the power of absorption coefficient of the sample, as is evident from Figure 5(a) of Ro et al. (1992). That this should be so, is trivially obvious from our Equation (6a) which depends on the volume concentration  $N$  via the parameter  $\lambda$ .

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# Experimental Phylogenetic Analysis of a Greek Manuscript Tradition

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## Abstract

The manuscript tradition of Gregory of Nazianzus' Homily 27 was used as a case-study to illustrate how phylogenetic methods may be applied to philological problems. Using this Greek text, we have compared three methods: two statistical methods of classification (multidimensional scaling and clustering) and a phylogenetic method used in biology. Multidimensional scaling and clustering do not make any assumption on the sequence of events explaining the different states of the text and are exclusively based on similarities between objects. On the other hand, the phylogenetic method compares different arrangements of objects and validates the arrangement (tree) requiring the smallest number of changes (evolutionary events) as the most probable. In our case, phylogeny proved to be an extremely efficient tool to classify different states of a text. Beyond this practical interest, strong conceptual parallels may be drawn between philology and biological phylogeny. Both disciplines aim to classify objects (living beings or manuscripts) and to reconstruct the sequence of events explaining the present diversity. They share common theoretical assumptions and difficulties (homoplasies, contamination) but diverge on some points. Phylogeny is an efficient tool but convergences and divergences between philology and biology remain to be critically discussed in order to make it a fully appropriate tool.

## Introduction

Over the last few years, it has not been unusual to read articles written by philologists and biologists together. Phylogenetic approaches appear to be a very powerful tool, not only in the field of biology but also in philology.<sup>2</sup>

Most pagan texts from Antiquity are known only through a very narrowly preserved manuscript tradition. Some even escaped by chance from irremediable disappearance.<sup>3</sup> Moreover, for these texts, there is rarely any direct witness at all

before the ninth century or later, which means a gap of several centuries between the time the text was written and the time from when we may reconstruct its history. This scheme is rather different from the transmission of a medieval text, of which manuscripts may be contemporary. It is also different from the tradition of a Christian late antique writer, whose works are preserved in a overabundant number of medieval manuscripts. Each of these situations requires an appropriate method of investigation.

### Nazianzus Homilies

The 45 homilies of Saint Gregory of Nazianzus (ca 330-390 AD), one of the Cappadocian Church Fathers<sup>4</sup> and a bishop of Constantinople during the second ecumenical council, have not yet been critically edited.<sup>5</sup> This lack of a reliable edition, based on a comprehensive history of the text, can be explained by an overabundant and intricate tradition consisting of about 1200 Greek manuscripts. The mass of data provided by the collation of the manuscripts is far too numerous to be handled by paper-based methods (on index cardboard). Computer-aided methods of collation exist indeed, such as Collate,<sup>6</sup> but for many reasons we preferred to create our own way of encoding.<sup>7</sup> It must be added that it is really difficult to find significant readings that clearly divide the manuscript tradition, because those texts have been carefully copied, corrected and even collated.<sup>8</sup>

Over the last few years, several methods using computer and mathematical algorithms have come to light.<sup>9</sup> In the case of Gregory of Nazianzus we tested three methods: multidimensional scaling, clustering and phylogeny, all applied to Homily 27.<sup>10</sup>

### Dataset : Homily 27

Homily 27 is preserved in 126 Greek manuscripts,<sup>11</sup> four ancient translations into Latin,<sup>12</sup> Armenian<sup>13</sup> and Syriac (two translations: S1 and S2)<sup>14</sup> and an old printed edition.<sup>15</sup> Without taking into account orthographical and phonetical readings, there are 665 variants on 550 variant locations. The collation was recorded into a data base, where the record unit is the variant location: one word or one group of words for which there are more than one reading. The way of delimiting the variant locations is empirical. It is based on two principles: on the one hand, an attempt at understanding how the change may have occurred (although we don't necessarily know what is the primary reading) and on the other hand, a clustering of as many as possible readings that may depend on one another.<sup>16</sup> For each variant location and each manuscript, the readings that are different from the reading of the reference text are recorded. To make it easier, we chose as a reference text the only comprehensive edition, made in the eighteen century and reproduced in Migne's *Patrologia Graeca*.

From this encoding, a cross table summarizes the data and is used in any mathematical, statistical or biological data processing.

### Three Methods

**Multidimensional Scaling** (MDS) is a method that spatially organizes and clusters objects on the basis of a distances matrix.<sup>17</sup> In our application of the method, Hamming distances were calculated between the manuscripts of Homily 27.<sup>18</sup> (The Hamming distance is a measure of the number of items in two ordered lists that do not agree.) The two dimensional representation (figure 1) of these data is a reduction of a 156 dimension space in order to focus on the main relationships between manuscripts. This rearrangement is based on a minimization function algorithm that limits the impact of the reduction of the number of dimensions on apparent distances between objects. The MDS is very sensitive to a lack of data within some objects as it will distort distances. The MDS clustering is based on similarities between objects: the method does not assume any model of transmission of the variation.

**Wattel's Method** –Based on a model of transmission such as phylogeny, Wattel's method is a graph showing possible relationships between objects displayed from a central arbitrary original node.<sup>19</sup> As this method is also affected by missing data, results are very similar to those obtained with MDS (data not shown).

**Phylogenetic Parsimony** – The objective of phylogeny is to order a collection of objects (e.g., biological taxons,<sup>20</sup> manuscripts) related by a common history on the basis of variable elements (e.g., morphological and physiological traits, genetic sequences, protein structure).

Most biological methods to reconstruct phylogenies are based either on a parsimony criterion or on distance-based approaches. In a parsimony approach, the first step is to list all the possible topologies (i.e., trees) linking the different objects and then select the most probable tree. The criterion of selection is the minimization of number of changes. As the number of possible trees increases exponentially with the number of objects, this approach requires intensive computation facilities.

The methods based on distances assume the prior calculation of a distances matrix between all combinations of objects. Different clustering algorithms (Neighbour Joining, UPGMA, ...) make sense of this matrix. While parsimony approaches assume a time sequence, methods based on distances do not. Nevertheless, the specific applications of distance based approaches to the reconstruction of manuscripts history are time-based: the greater the distance between two manuscripts, the larger the time span between them.

## Results

The MDS representation (figure 1) highlights two groups of manuscripts: a large one (A) and a smaller one (B). The composition of these groups with respect to philology will be discussed later. Ten manuscripts are not properly classified as they contain many lacuna.

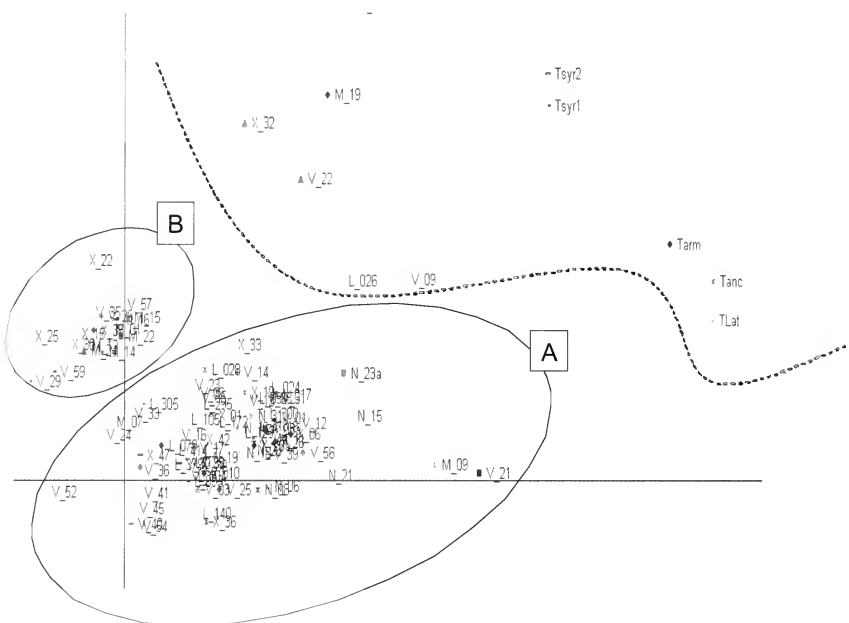


Figure 1 : Results of an MDS analysis of 126 Greek manuscripts and five translations of Homily 27 by Gregorius Nazianzus. Two clusters are clearly distinguished. Manuscripts above the interrupted line are misclassified as they contain missing data.

On the parsimony based phylogram, two main groups are clearly distinct. These two groups are identical to those identified by the MDS method but they include the ten manuscripts unclassified in the MDS representation. One important discrepancy is location of TSyr1 and TSyr2. By a parsimony approach, these two witnesses appear close to manuscripts X.22 and V.29, on a branch which is nearby the origin of branch B.

In accordance with our knowledge of the history of the text, two groups are identified. In group A, we found all the N collections with part of the X collections. In group B are all the M collections with a few X collections. The Syriac versions (TSyr) are clearly specific, but somehow linked with group B. The distinction between M and N collections is based on the order of the homilies within the manuscripts: two different orders are clearly identified. The situation of X collections is more complicated, for each manuscript follows its own order, more or less similar to one of the two main orders (M or N) or totally different. The origin of X collections

is still controversial. The methods used may help the philologist to reclassify X manuscripts in one or the other of the two known families.

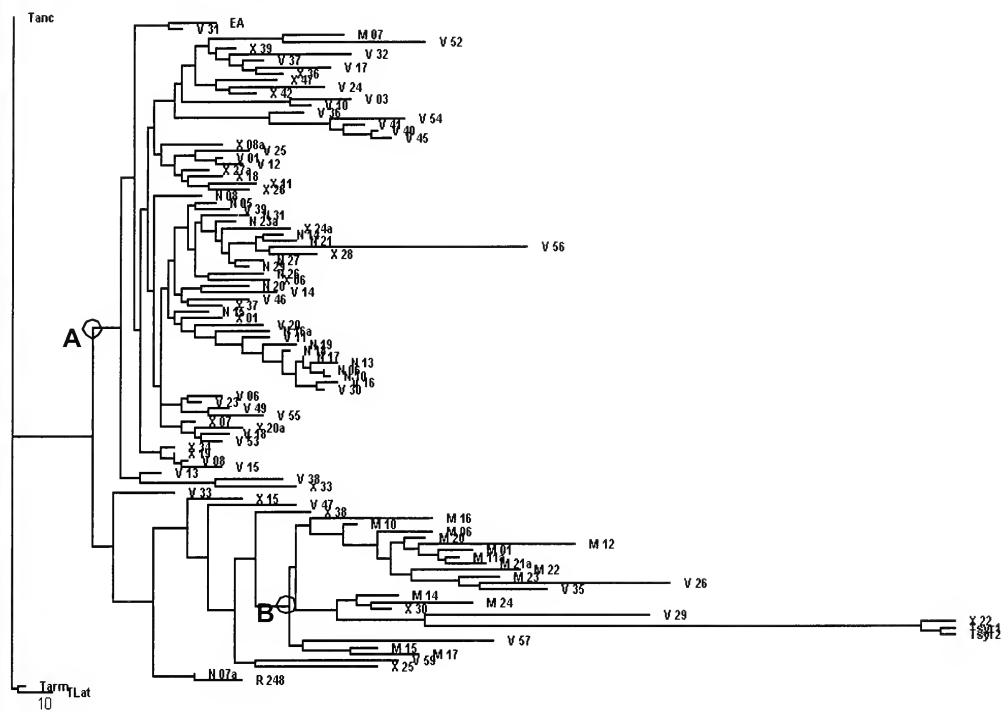


Figure 2: Phylogram of the 110 manuscripts of the homily 27 of Gregory of Nazianzus based on a phylogenetic approach.

We do not want to go further on into details about validity of these results. As to proving that phylogenetics have been successfully used on Gregory of Nazianzus' textual tradition, we may only say that the first edition based on examination of the whole manuscript tradition, thanks to phylogenetics, will be published in the next few months.<sup>21</sup> We find it more interesting to develop here some insights about what phylogenetics may offer to philologists.

## Discussion : The Use of Phylogeny in Manuscript Tradition.

### *Computational Methods are Efficient*

All the methods we used to reconstruct the history of Homily 27 by Gregory of Nazianzus were efficient in proposing relevant clusters of texts. Phylogeny based on a parsimony approach was more efficient than a MDS method.

This method is interesting for people working on textual traditions, not only because it is efficient as a clustering tool but also due to strong conceptual convergences between the two disciplines. Phylogeny is a method of classification of living

beings that utilizes hypotheses of character transformations to group organisms hierarchically and then interprets these relationships as genealogical. Transfer to a manuscript tradition seems promising. Nevertheless, some points of discussion have to be raised:

**Multiple trees** – In most cases, the phylogenetic method does not give a single tree but a series of equivalent trees which get the same likelihood of occurrence. These multiple trees may be a good answer to Bedier's criticism of the stemma approach.<sup>22</sup> He said that he refused to draw a stemma of the tradition he was working on, not because he was not able to draw one, but because he was able to draw too many different stemmata that were equally valid. Of course, a stemma is always a hypothesis either in biology or philology. Decision on the best stemma will be based on an intrinsic knowledge of philology and on external information on the status of manuscript. The phylogenetic method is not an automated substitute to philologist work but an aid to decision.

**Homoplasy vs. homology** – All similarities are of interest in order to prove a common ancestor between two manuscripts, but not all of them reveal a true kinship. For biologists, bats and birds both have wings but they are not closely related. Other features set them apart (lactation, fur) and bats are closer to rats than to birds. The common emergence of wings in birds and bats is due to a phenomenon called evolutionary convergence or homoplasy: the same trait emerges independently in two species due to environmental factors. In a manuscript, orthographical variations may induce this convergence: two scribes with the same orthographical or even dialectal habits will implement identical variations even though they work on different lineages of a manuscript tradition (Howe et al., 2001).

**Contamination** – A major issue in a text tradition is contamination. In our case, manuscript X<sub>22</sub> has difficulties in finding its place in the stemma. In some analyses it sticks to group B, in other cases, it will be very close to Syriac versions. Actually, X<sub>22</sub> is probably a hybrid manuscript: most of the text is copied on the B tradition but some parts of the text were copies out of manuscripts of the A tradition. If these contaminations affect important sections of the text, it may cause misclassification of texts.

**Progress** – A major hiatus between biology and philology is the impact of time. For the philologist, time is a degradation factor which drives the accumulations of errors and mistakes in a text up to the loss of the original information. From a biological point of view, time is the main engine of change, a driving force to progress. This apparent antagonistic role of time is to be considered with caution. Progress in biology is a dangerous concept: evolution leads to an increase of complexity but it is difficult to decide whether a bacteria is more adapted to its environment than a human being. From the philological point of view, the successive transformations of the text – transformations of different types: translation, com-

ments, variants – contribute to the survival of the initial message with a concomitant loss of the original text.

## Conclusion

Computational tools, and more specifically phylogeny methods are very helpful in the development of philology. They are particularly relevant when the analysis is based on a large corpus of data.

This tool is fascinating but has to be critically implemented. It provides the philologist with one or several propositions of classification of manuscripts. The final interpretation has to integrate this mathematical approach in a wider framework. In most cases, the boundary of interpretation is the lack of information. The biggest computer cannot palliate a burned library but it may help to make sense of the available information.

## Endnotes

- <sup>1</sup> Prof. Philippe V. Baret and Anne-Catherine Lantin are at the Faculty of Biological, Agricultural and Environmental engineering, Université Catholique de Louvain, Dr. Caroline Macé is a researcher at the Institute of Philosophy, Katholieke Universiteit Leuven, Marc Dubuisson is a doctoral student at the Department of Classics, Université Catholique de Louvain. Writing this paper has been a longstanding project, starting at Cambridge University, where the authors were invited by Dr. Natalie Tchernetska to give a lecture at the Department of Classics in May 2002, and ending at De Monfort University, where they attended a workshop organized by Prof. P. Robinson in April 2003.
- <sup>2</sup> For example, the article of P. Robinson and of a team of biologists from Cambridge, published in *Nature*: Barbrook, A.C. *et al.* (1998) The phylogeny of the *Canterbury Tales*, *Nature* 394, 839. See now Howe, C. J. *et al.* (2001) Manuscript evolution, *Trends in Genetics* 17, 147-152. It was not something new though: Platnick, N.I. and Cameron, H.D. (1977) Cladistic methods in textual, linguistic and phylogenetic analysis, *Systematic Zoology*, 26, 380-385. A good introduction is to be found in this unfortunately unpublished thesis: Moura, M. (2002) *Méthodes phylogénétiques: de la systématique en biologie et de ses applications en philologie (stemmatologie) et en linguistique historique*, Université de Lausanne, Faculté des Lettres [www.unil.ch/imm/docs/Trav\\_Etudiants/MouraMemoire.pdf](http://www.unil.ch/imm/docs/Trav_Etudiants/MouraMemoire.pdf).
- <sup>3</sup> Reynolds, L.D. and Wilson, N.G. (1974), *Scribes and Scholars: A Guide to the Transmission of Greek and Latin Literature*, Oxford, rev. ed.
- <sup>4</sup> The title of "Church Father" is given to the most important Greek and Latin writers whose writings are considered founding texts of the tradition of the Church and who belong to the "Patristic age" (from the second to the sixth century; this period is also called "late Antiquity"). The literary success of some of them, like Augustine, the Cappadocians (Gregory of Nazianzus, Basil of Caesarea and Gregory of Nyssa) or John Chrysostomus, was so important during the middle ages that they have been copied and quoted an uncountable number of times: Amand de Mendieta, E. (1987) Un problème d'ecdotique. Comment manier la tradition manuscrite surabondante d'un ouvrage patristique, in *Texte und Textkritik. Eine Aufsatzsammlung*, hrsg. von Dummer, J. (Texte und Untersuchungen 133), Berlin, 29-42.
- <sup>5</sup> See a survey of the international project edition of Gregory's *Homilies* carried on at the University of Louvain: <http://nazianzos.fltr.ucl.ac.be/>.
- <sup>6</sup> Cf. Robinson, P (1994) *Collate : Interactive Collation of Large Textual Traditions*, version 2, Oxford University Centre for Humanities Computing.
- <sup>7</sup> Collate may be used for any manuscript tradition. The aim is to have at the end a complete transcription of all available manuscripts, with all their orthographical and scribal characteristics. This tool was created primarily for traditions of medieval texts, where each manuscript has a value as such, as an unique witness

of a precise moment within the history of text. In a case like Gregory's homilies, we are using the history of the text mainly as a way to the archetype, the furthest possibly reconstituted common ancestor of the tradition. Thus, we did not want to take into account a huge number of insignificant variants. Phonetics is a big issue in Medieval Greek, for many vowels started early to be pronounced "i" – this phenomenon is called iotacism – and the difference between long and breve vowels tended to disappear. That would be confusing.

- <sup>8</sup> There is a large number of marginal or other corrections in most manuscripts. Moreover, Gregory's homilies were loudly read in church or learnt by heart at school. This "vivid" knowledge of the text may have played a role within the text transmission, although copying remains a very conservative process. "Contamination" is by the way an unsatisfactory concept that describes only the result of several very different causes and that is often wrongly used. To take it simply, one might detect a contamination when a manuscript is sharing secondary readings ("mistakes") clearly characterizing two or more families or when a group of manuscripts clearly related have also secondary readings of another family.
- <sup>9</sup> Duplacy, J. (1975) Classification des états d'un texte, mathématiques et informatique: repères historiques et recherches méthodologiques, *Revue d'Histoire des Textes*, 5, 249-309 ; Glenisson, J. (ed.) (1979) *La pratique des ordinateurs dans la critique des textes. Actes du Colloque international tenu à Paris du 29 au 31 mars 1978* (Colloques internationaux du C.N.R.S. 579), Paris ; Van Reenen, P. and Van Mulken, M. (eds.) (1996) *Studies in Stemmatics*, Amsterdam - Philadelphia.
- <sup>10</sup> This was the subject of C. Macé's doctoral dissertation, defended on May 2002 at the Catholic University of Louvain: *La tradition des discours de Grégoire de Nazianze. Edition critique du discours 27*.
- <sup>11</sup> A complete list of manuscripts is available on line: <http://pot-pourri.fltr.ucl.ac.be/manuscripts/nazianze/default.cfm>.
- <sup>12</sup> The Latin translation was made at the end of the fourth century by a famous Italian monk, Rufinus of Aquileia: Engelbrecht, A. (ed.) (1910) *Tyrannii Rufini Orationum Gregorii Nazianzenii novem interpretatio* (Corpus Scriptorum Ecclesiasticorum Latinorum 46), Wien - Leipzig.
- <sup>13</sup> The Armenian translation is anonymous, made probably around 500: cf. Lafontaine, G. and Coulie, B. (1983) *La version arménienne des Discours de Grégoire de Nazianze. Tradition manuscrite et histoire du texte* (Corpus Scriptorum Christianorum Orientalium 446), Louvain.
- <sup>14</sup> The first Syriac translation (S1) was made in the second third of the fifth century; Paul of Edessa made a second translation in Cyprus in 624-625 (S2): cf. Detienne, C. (2000) Grégoire de Nazianze dans la tradition syriaque, in *Studia Nazianzenica* I, ed. by Coulie, B. (Corpus Christianorum. Series Graeca 41), Turnhout - Leuven, 175-183.
- <sup>15</sup> This *editio princeps*, made by Marcus Musurus on the basis of several unknown and possibly lost manuscripts, was published in 1516 in Venice: cf. Bertolini, M. (1988) L'edizione aldina del 1516 e il Testo delle Orazioni di Gregorio Nazianzeno, *Studi Classici e Orientali* 38, 383-390.
- <sup>16</sup> For example, we tend to put on the same variant location an inversion and an omission (of one of the two words or groups of words concerned by the inversion), because it may happen that an inversion is the result of a corrected omission (the completed words are put on the wrong place), even though omissions and inversions may happen purely coincidentally on the same place. Indeed, larger is the manuscript tradition, more it gives rise to hazard.
- <sup>17</sup> Borg, I. and P. Groenen, P. (1997) *Modern Multidimensional Scaling. Theory and Applications* (Springer Series in Statistics), New York-Berlin-Heidelberg.
- <sup>18</sup> Macé, C., Schmidt, T. and Weiler, J.-F. (2001) Le classement des manuscrits par la statistique et la phylogénétique: les cas de Grégoire de Nazianze et de Basile le Minime, *Revue d'Histoire des Textes*, 31, 243-276.
- <sup>19</sup> Wattel, E. (1996) Clustering stemmatological trees, in *Studies in Stemmatics*, edited by Van Reenen, P. and Van Mulken, M., Amsterdam - Philadelphia, 123-134.
- <sup>20</sup> A division in a phylogenetic hierarchy is known as a taxon. For example, a genus is a taxon grouping together different species.
- <sup>21</sup> The *editio maior critica* of Homily 27 by C. Macé will appear soon.
- <sup>22</sup> Reeve, M.D. (1986) Stemmatic Method: "Qualcosa che non funziona?", in *The Role of the Book in Medieval Culture*, ed. by Ganz, P. (Bibliologia 3), Turnhout, 57-69.

**Science Policy:**

# **Constructing a Planetary Defense Regime to Reduce International Terrestrial Insecurity**

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*Readers of the Journal are invited to respond to this science policy proposal. Send your comments to [Editors@washacadsci.org](mailto:Editors@washacadsci.org) to be considered for publication in the Journal.*

## **Abstract**

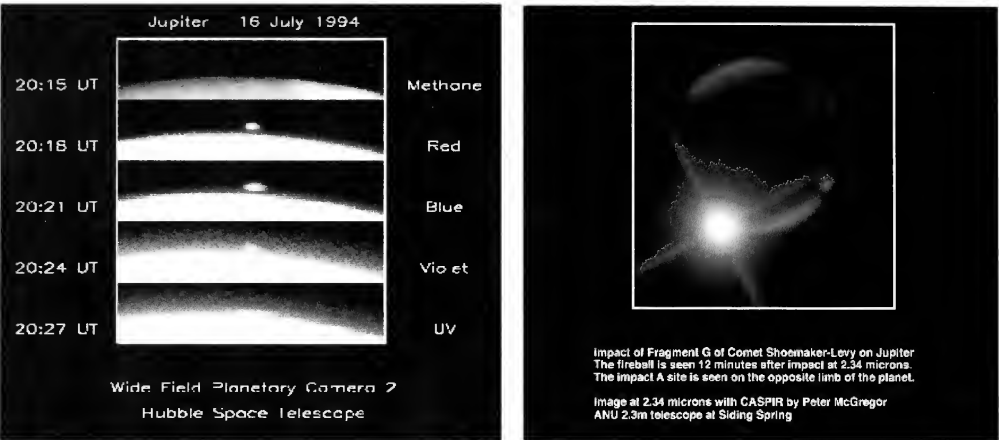
Objects in space near Earth, including asteroids, comets, and man-made space debris, are known as Near Earth Objects (NEOs). If they are in Earth Crossing Orbits (ECOs) around the sun, slight changes in their orbits can result either in potentially catastrophic collisions with Earth, or in avoiding such collisions. This paper argues that existing terrestrial political insecurity can be lessened by constructing a planetary defense regime (PDR) to vigorously detect, probe and decide how to best redirect NEOs. Through engaged diplomacy by the United States, the very acts of proposing, planning and beginning the construction of a PDR with other countries will likely create necessary and sufficient conditions for reducing the probability that a PDR will be weaponized, either by small or great powers.

## **Introduction**

In the years following the massive impacts of fragments from Comet Shoemaker-Levy 9 into Jupiter in 1994 (see illustration 1 below), scientists around the world have been diligently pursuing the optical detection of asteroids and comets that are on Earth Crossing Orbits (ECOs). Objects that might possess ECOs (including man made space debris) are also known as Near Earth Objects (NEOs). Slight changes in the orbits of these objects around the sun can result in potentially catastrophic collisions with Earth or conversely in the avoidance of such naturally occurring collisions.

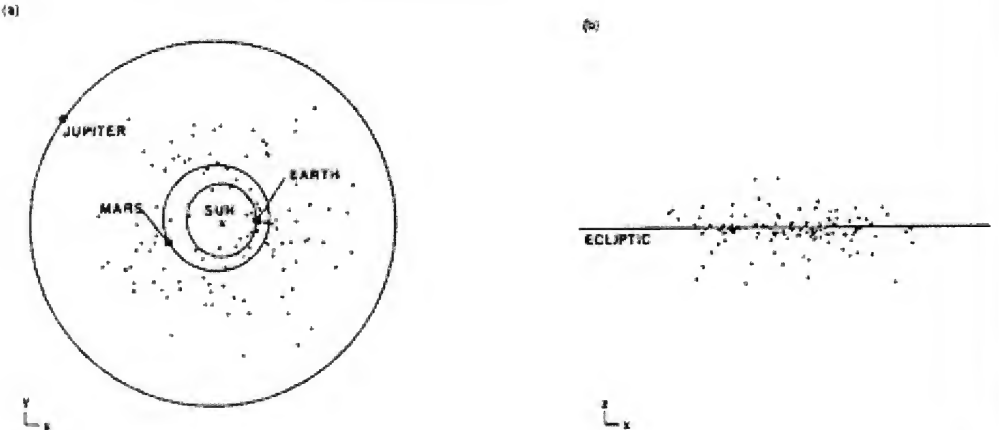
“...The next impact of a mile size object will probably happen without any previous discovery of it at all. The first thing you will know is when you feel the ground shake and see the plume of fire coming up over the horizon.” So said David Morrison, Director of Space, NASA Ames Research Center, Moffett Field, California.

Figure 1 best illustrates the overall environment in which a PDR would be constructed to protect Earth from unnecessary harm.



**Illustration 1.** Jet Propulsion Laboratory, NASA. Top 20 Comet Shoemaker Images. 12. [MISSO Image of Fragment K Impact Plume](#) (19 July 1994). 17. [Hubble Image of Fragment A Plume](#) (16 July 1994). Last updated March 2000. <http://www.jpl.nasa.gov/s19/top20.html>

Figure 1. Positions of Known Earth Crossing Asteroids



**Left:** Positions of known ECAs [Earth crossing asteroids] on September 23, 1991 in an ecliptic North Pole projection of the inner solar system. The direction of the vernal equinox is to the right. Orbits and locations of Earth, Mars, and Jupiter are also shown.

**Right:** Ecliptic plane projections of ECAs, on the same scale as (a). The ecliptic is shown as the horizontal line (Space Studies Institute, Princeton, New Jersey).

A more up to date catalogue of NEOs as well as how both the United States Air Force, NASA and international partners currently “scan the skies” can be found at the NASA Ames Research Center website at [www.impact.arc.nasa.gov](http://www.impact.arc.nasa.gov).

A United States Air Force (USAF) sponsored research paper has provided some useful quantification of the NEO threat in table form. This table includes the NEO threat in the list of statistical median "day to day" pedestrian threats in the United States. Table 1 might even be more useful if it were re-calculated to represent globally averaged pedestrian threats.

**Table 1: Relative Probability of Death by Asteroid Impact** (From Chapman and Morrison)

Chances of Dying from Selected Causes in the USA

Motor Vehicle Accident	1 in 100
Murder	1 in 300
Fire	1 in 800
Firearms Accident	1 in 2,500
Electrocution	1 in 5,000
Passenger Aircraft Accident	1 in 20,000
<b>ASTEROID IMPACT</b>	<b>1 in 25,000</b>
Flood	1 in 30,000
Tornado	1 in 60,000
Venomous Bite or Sting	1 in 100,000
Fireworks Accident	1 in 1 million
Food poisoning	1 in 3 million
Drinking Water with EPA limit of TCE	1 in 10 million

Air University Into the Future. Preparing for Planetary Defense: Detection and Interception of Asteroids on Collision Course with Earth. White Paper on Planetary Defense, Spacecast 2020. 25 May 1994. [www.fas.org/spp/military/docops/usaf/2020/app-r.htm](http://www.fas.org/spp/military/docops/usaf/2020/app-r.htm)

Obviously, catastrophic NEO strikes occur less frequently than floods and tornadoes, but Table 1 reflects an enormous statistical weighting factor; an NEO strike can cause apocalyptic disruption, up to the point of human extinction. Ironically, the human species now has the capability to *avert* NEO strikes while it is only possible to *control* or *mitigate* the damage caused by tornadoes and floods.

Clark Chapman of the Southwest Research Institute in Boulder, Colorado has said of the NEO threat that the "potential consequences are horrific, exceeding any other natural hazard and roughly that of an all-out nuclear war."<sup>1</sup> He went on to say that:

Unlike the dinosaurs, the big picture is that we do have the capability and intelligence to protect ourselves from this threat. The questions are...will we take a gamble and submit to fate? Or do we undertake a measured, rationale response? The first element is to educate ourselves and our leaders about this issue, and rationally decide what fraction of our budget should be devoted to protecting our planet.<sup>2</sup>

Chapman emphasized that once all near-Earth asteroids have been located, comets remain a "lingering hazard." Because comets travel faster than asteroids, they can enter the inner solar system on short notice. However, comets are brighter than asteroids and can be detected at farther distances from Earth. Comet Hale-Bopp slipped by Earth in 1997 and was likely 100 times more massive than the object that wiped out the dinosaurs. "It was a big one, and it was only discovered something like a year before it came in...Astronomers are just learning how to communicate with each other. But the relevant political agencies are not prepared to listen and act," Chapman said.<sup>3</sup>

The National Aeronautics and Space Administration (NASA) currently fund several efforts to search for NEOs. Foremost among them is the Lincoln Near Earth Asteroid Research program (LINEAR) which in recent years has been funded in the range of \$4 million a year. LINEAR is operated by MIT's Lincoln Laboratories, in conjunction with the United States Air Force (USAF) to scan the skies for NEOs. Since 1998, LINEAR has discovered about 1,000 NEOs of various sizes and compositions that likely range from pure iron to loosely compacted gravel. It is critical that the international community confirm that most of these NEOs are not current threats to Earth, and also to catalogue them and monitor their orbits. Over 600 NEOs one kilometer in diameter or larger have been found to date. Astronomers estimate that there are some 1,000 NEOs of comparable size. At current discovery rates, NASA is projected to achieve its goal of discovering 90 percent of the statistically projected NEOs of this size by 2008.<sup>4</sup>

Brigadier General Simon "Pete" Worden, who once served as Deputy Director of Operations, United States Space Command [now serving as Director of the Office of Transformation, Space and Missile Systems Center/Los Angeles Air Force Base] is the chief proponent of adopting military command and control of technologies for the mitigation of NEOs.<sup>5</sup> Whenever General Worden speaks on NEOs, he always emphasizes that he is expressing his personal views and not those of the USAF or the DoD. "For fear...for greed...for curiosity. Asteroids are about the only thing in space that combines all three of those," Worden has concluded.<sup>6</sup> Worden is referring to minerals in abundance on asteroids, such as platinum when he speaks of greed. Greed may be a useful component of a PDR, as will be discussed shortly.

Of growing concern are the estimated one million NEOs that are 50 meters across or larger. NASA does not currently have the facilities to search for these smaller but still significant threats. An example of such an object was the discovery of 2002 MN by LINEAR on 17 June 2002 (days after Worden made the above statements on fear, greed and curiosity), estimated to be between 50 and 120 meters across. 2002 MN passed within 120,000 kilometers of the Earth (inner solar system) on 14 June, three days before its discovery. Had it struck Earth in the right place, it could have destroyed a large city.<sup>7</sup>

While NASA is currently focused on finding one kilometer or larger NEOs, because they have the potential for global devastation, NASA is also initiating a feasibility study for conducting searches for these smaller objects.<sup>8</sup> General Worden argues that more attention should be devoted to these "Tunguska-class" objects because they can strike up to several times per century with the destructiveness of a nuclear weapon.<sup>9</sup>

The word "Tunguska" refers to an event in 1908 in which a 50 meter object exploded in the air above the Tunguska River in Siberia, leveling over 1,000 square kilometers of rural forest. This blast released an amount of energy 1000 times greater than the nuclear weapons dropped on Japan in 1945. Had the object entered Earth's atmosphere only three hours later, Earth's rotation would have created a 10 to 15 megaton air burst over Moscow. Scientists still dispute whether this object was an asteroid, comet or other mix of ice and rocky material.<sup>10</sup>

This paper is being written for an audience in a "hyper power."<sup>11</sup> As such, the arguments in this paper rest on the belief that it is the responsibility of the United States to dispel the anxiety currently exhibited towards her by other powers around the globe, large and small. Ironically, countermeasures designed for the protection of people on Earth might also exacerbate an already insecure inter-national security environment, particularly in the military space arena. One only needs to look at the self-destructive history of the 20<sup>th</sup> century (especially World War I), as Carl Sagan did and the events of September 11, 2001 to easily contemplate suicidal "madmen" scenarios with respect to a PDR. Sagan reasons:

...if you can reliably deflect a threatening worldlet so it does not collide with the Earth, you can also reliably deflect a harmless worldlet so it does collide with the Earth...If we develop and deploy this technology, it may do us in. If we don't, some asteroid or comet may do us in. The resolution of the dilemma hinges, I think, on the fact that the likely timescales of the two dangers are very different – short for the former, long for the latter...The reliability of world political organizations and the confidence they inspire will have to make significant strides before they can be trusted to deal with the problem of this seriousness... we can afford to wait...<sup>12</sup>

### **Philosophical Blueprint for Planetary Defense**

What Sagan and other realists may not appreciate is that perhaps only when world political organizations face problems that concern the continued existence of the human species, can revolutionary advancements be made in these institutions.

David Lake suggests that choices exist, apart from the inter-locking alliance structure of traditional balance of power politics. He argues that in an anarchic world, security, like any good must be manufactured by politics, which he defines as any

actor that has or could have a history of self-rule. Lake believes that international cooperation cannot proceed unless some effective governance structure can be constructed at an acceptable cost to whatever collection of polities is mustered. In a world structure, presently based on self-interest and opportunism, influencing the behavior of others is critical and is more achievable if done through appeals to basic human needs, especially the risk of death.<sup>13</sup>

In addition to ensuring the preservation of the human species, it can be argued that a cooperative PDR will also build prestige, confidence and relations among powers, great and small alike. These secondary effects, while seemingly separate serve as the keystones to the architectural analogy that is present throughout this paper: a cathedral of refuge against fire and brimstone. The smaller the units of polities (grains of powder versus pebbles), the greater the density and impermeability the eventual "mortar" will have when it cures – in terms of vigilance in the overall dome or arch of planetary defense that is to be constructed.

This conceptualization therefore makes it easy to envision a regional or continental approach to planetary defense, rather than a great power or state-based approach through the United Nations. In regard to detection, there is much that even sub-state polities can contribute to a PDR.

Consistent with this approach to a PDR, the Planetary Society's Shoemaker NEO Grant Program currently awards \$5,000 to \$8,000 to qualified amateur astronomers each year to increase the rate of discovery and follow-up studies (particularly in the southern hemisphere) of NEOs in countries as diverse as Brazil, Czech Republic, Slovenia, United States and Uruguay.<sup>14</sup> Note that these awards are made to individuals in countries and not to countries.

There are arguments to be made on both sides for whether space-based tracking or Earth-based tracking is more cost effective. However, at the present time what the international community needs are more tracking stations to detect new objects on ECOs as well as monitor the orbits of known NEOs, whether they are Earth-based or space-based. A sense of vigilant urgency rather than optimum systems development is what is needed if national governments are serious about ensuring the preservation of human life on Earth, so that humankind may have a chance to explore beyond low Earth orbit.

For the same reason, this same sense of urgency might also be applied to codifying preventive measures against the potential of a cascading effect occurring between existing space debris and the International Space Station.

### **Laying the Foundation for Planetary Defense**

The above conditions (met through commitment based on political perception) are crucial and likely sufficient for an effective PDR to be constructed. For the

international community to meet and sustain these key conditions, creative political-diplomatic efforts will be required. This can be achieved publicly or privately. It is generally probable that public political statements will not bring about these conditions. They are too complex and open to misinterpretation or exploitation by domestic political opponents. It is preferable that initiation of this regime be initiated through private diplomacy. However, at some point, there must be public disclosure of this regime, to avoid domestic misunderstandings, paranoia and resistance.

An argument can be made that public disclosure of a PDR may cause panic. This assertion can be argued the other way around. If done through effective global political leadership, global citizen knowledge of and *involvement* in a PDR might initially bring about solidarity of purpose among citizens worldwide that may create the effect of an informal *global citizenry*. This concept of a *global citizenry*, emerging naturally out of the norm and acceptance of entwined interests to maintain a PDR *for, of and by* people might be transferred more readily into other areas of peace-making and the maintenance of human civilization than existing "people to people" programs among nation states. The prospect of citizens worldwide, feeling empowered and connected; either vicariously through regional space programs or through smaller contributions to a PDR might be a positive development in the current world situation.

### International Good Will by Design

For such a manifestation to occur, the United States cannot be perceived as "running the show," as if a PDR is a Hollywood script. America would do better to "request" and "invite" technological assistance from the rest of the world. It would also be in the short term strategic interest of the United States to at present jointly deploy a PDR for the sole purpose of rebuilding the depleted prestige of large nations in Europe and Asia in a positive way; including but not limited to France, China and North Korea, each of which has ballistic missile capability.

The problem of depleted prestige has been the result of obvious U.S. dominance; economically, socially, politically and militarily. From the perspective of the depleted, it does not matter whether this dominance has been benign or not.

### Countering Sagan's "Mad Man" Assumption

Upon revelation of an international agenda for planetary defense, realists in all nations most likely will argue against it based on the "mad man" assumption articulated by Sagan. Here are a few counterarguments in preparation for that eventuality: 1) Earnest international scientific exchange of information on NEOs in conjunction with multilateral planning of operations and institutional resources devoted to

maintaining planetary defense will divert resources devoted to the preparation for armed conflict by nation states. 2) While this will take away from resources to preempt terrorist acts against states, the result will still be a net decrease in inter-national insecurity. 3) Subsequent and increased intelligence sharing among nation states, a likely result of this second point will help bring the choke hold on terrorism (originating from sub-states, rogue states and failed states) to the point of fatal asphyxiation.

### **Harnessing the Entrepreneurial Spirit for Planetary Defense**

Economic liberals, known as entrepreneurs in the space development community would accept Lake's thesis that planetary security is essential but they might argue against planetary defense being built solely on political grounds. Part of their security calculus focuses on Lake's idea that security can also be defined as the absence of external coercion in the allocation of wealth.<sup>15</sup> They resist the idea that planetary defense can only be built by governments and tax dollars.

Their argument, with considerable merit, is that these tax dollars, along with loosened restrictions on private sector mining of precious metals on asteroids would be more efficient in building the knowledge and skill set necessary for diverting asteroids.

The fallacy of economic liberals only emerges when they suggest that *only* a focus on economic competition in space will yield better results than a dedicated and international endeavor between governments to ensure the preservation of the human species. Still, it might be advisable for governments to discuss with economic liberals and among themselves how to create profit friendly regulatory and tax environments for entrepreneurs and how they may foster cooperation among eventual multinational asteroid mining firms.

In the future, the inevitable actions of economic liberals that do not serve the public good, such as exploitation of asteroid mining labor or collusion of prices over the resources they mine, must be strongly regulated by governments. Paul Doremus and Simon Reich argue that states still charter multinational corporations and shape the operating environment, in which they flourish, by retaining authority to steer their activities.<sup>16</sup> Nothing less should be expected in the space security arena.

### **Predictable Serendipity as a Component of Planetary Defense**

Some humanitarian critics of a PDR, though not opposed to an international security regime might argue that the NEO threat is not the material with which to build the cathedral. Instead of building the arch of planetary defense, they feel, perhaps legitimately that earthbound threats such as disease or rapid climate change are more

likely threats to the demise of the human species. These distracters might be persuaded that *all* fields of human vigilance through inquiry should be investigated simultaneously because the process of true discovery is interdisciplinary and serendipitous in nature.

Still, under current economic constraints some negotiating framework on resource allocation for research and development, based on the best scientific assessment of threats to humanity will need to occur. Perhaps the United Nations Educational, Scientific and Cultural Organization (UNESCO) or a league of national science boards will be the best forums in which to resolve these inevitable and legitimate discussions.

### Final Structure: Beating Shields, Swords and Plowshares into a PDR

Despite its uniqueness, any proposal for a PDR will exist in the context of precedents set in near term history. Following Operation Desert Storm in 1991, President George Bush addressed Congress and could have easily delivered a message couched in the rhetoric of realism. He did not. In a neo-Wilsonian, continentalist-constructivist manner, Bush declared:

...Tonight, we meet in a world blessed by the promise of peace...aggression is defeated. The war is over. This is *a victory for every country in the coalition*, for the United Nations. A victory for unprecedented international cooperation and diplomacy...*North America and Europe*, from *Asia and South America*, from *Africa* and the *Arab world*, all united against aggression. Our uncommon coalition must now work in common purpose: to forge a future that should never again be held hostage to the *darker side of human nature*...Now, we can see a new world coming into view. A world in which there is the very real prospect of *a new world order*. In the words of Winston Churchill, a world order in which 'the principles of justice and fair play *protect the weak against the strong*'...`A world where the United Nations, freed from cold war stalemate, is poised to fulfill the historic vision of its founders' [italics are the author's].<sup>17</sup>

Planetary defense captures the imagination even more. It promises to make *full use* of available global human capital and technology, as a means to achieve human dignity, security and solidarity. Global solidarity has always been an objective of the American experiment in republican democracy. *E Pluribus Unum, From Many One*: "The cause of America is, in a great measure, the cause of all mankind." Thomas Paine, *Common Sense*, 14 February 1776.<sup>18</sup>

As commerce, education, and the rapid transition of thought and matter, by telegraph and steam have changed everything, I rather believe that the great

Maker is preparing the world to become one nation, speaking one language, a consummation which will render armies and navies no longer necessary. **President Ulysses S. Grant, 1873.**<sup>19</sup>

### **NORAD as a Template for a Planetary Defense Regime**

The North American Aerospace Defense Command (NORAD) is an appealing template for a PDR. NORAD is an international organization, comprised of the United States and Canada. It is dedicated to preserving human life (in North America) by determining the velocity and trajectory of threatening objects that at one point would be outside of Earth's atmosphere (potentially launched by humans from other regions of the globe).

General Worden has revealed that the U.S. Department of Defense (DoD) has studied the issues of setting up an asteroid warning system and many others such as the National Space Society advocate that this should be a DoD responsibility. This system may or may not ultimately find a home within the NORAD and U.S Space Command missions in the Cheyenne Mountain Complex outside Colorado Springs, Colorado. An important step, Worden said, is to catalogue all objects that are potentially threatening to Earth, including small objects that could destroy a city. To accomplish this type of charting, military strategists now champion an existing space-based network of sensors that track Earth-circling satellites. These same "space sentinels" could also detect small asteroids.<sup>20</sup>

Worden advocates that additional funds should be devoted to building micro-satellites. Some of these tiny craft might be placed in a kind of sleep mode in parked orbits, ready to rendezvous with an intruding asteroid. These micro-satellites could offer close looks at NEOs in an effort to gather intelligence from which to develop the best countermeasures. Micro-satellites can also be configured to impact an object, adding extra energy to the body and putting it on a non-Earth-bound trajectory. While the low mass of micro-satellites would yield a negligible effect to an NEO on approach to Earth, if impacted far enough away from Earth would in most cases sufficiently alter the course of the NEO to avoid collision. "Before we start detonating nuclear weapons in space to move something, we ought to think long and hard how we really want to do this," Worden said.<sup>21</sup>

A research paper by USAF officers, submitted to the USAF "Air Force 2025" study concluded that the greatest challenge facing planetary defense will be coordination between nations, international organizations, DoD, NASA, academia and others in the scientific community. The young USAF officers who have assessed this threat realize that consolidation of national efforts will need to occur.<sup>22</sup>

### **Consolidating Existing Entities into a Planetary Defense Regime**

The key challenge for creating a PDR will be to determine the best architectures and deployment mechanisms (economic, social, political and military) for such a transformation of existing terrestrial security institutions. While transformation of NORAD for planetary defense is one option, a PDR might be constructed as either a part of the United Nations system, as a link between regional organizations such as NATO, the European Union (EU), Arab League, Association of South East Asian Nations (ASEAN), Organization of American States (OAS) or as a part of a joint effort by NORAD and the Asian-Pacific Space Cooperation Organization (APSCO), soon to be established in Beijing.

As an entity, APSCO is interesting for a number of reasons. Two of them are that of the 14 member nations, with UN endorsement; India, Australia and Japan have not yet been invited to join while Russia, Iran, Peru and Chile have been invited to join by China, the lead country. Still, Luan Enjie, minister of China's National Space Administration has said that the China is "...willing to join hands with people of all nations to make due contribution to the peaceful exploration and uses of space resources for the progress and common development of humankind." While not mentioning planetary defense explicitly it is significant that as part of its mission, APSCO is planning to better coordinate environmental protection, disaster reduction and resource exploration.<sup>23</sup>

Establishing a PDR will not be unlike the effort taken to create the U.S. Department of Homeland Security. There are currently about 20 under-funded and largely unincorporated agencies, missions, non-governmental organizations, university based programs and private initiatives around the globe that dedicate themselves to this common human endeavor.<sup>24</sup>

A key question that must be answered in creating a PDR is how to motivate these separate entities to take ownership of the new PDR entity given the natural inertia that exists as part of institutional momentum. One idea might be to locate joint military command and control elements of the PDR under the auspices of the International Space University (ISU) in Strasbourg, France. This institutional affiliation might draw precedent from the current NASA Deep Impact Mission to Comet Tempel 1, on schedule for impact on 4 July 2005 and housed within the University of Maryland.

Establishing this locale as headquarters for a PDR might also serve to bridge the transatlantic divide as well as being equidistant between Beijing and Washington. It should be noted that most of Europe's best minds on astronomy are located within their university system. The Near Earth Object Dynamics System, both at the University of Pisa, Italy and the University of Valladolid, Spain is one such example. The other symbolism that locating the PDR at ISU would signify is the notion that the best planetary defense is ultimately the free exchange of ideas.

### Countermeasures that Avoid International Terrestrial Insecurity

In certain instances, one option to redirect a fast approaching asteroid on collision course with Earth is to send humans out to it to perform a variety of countermeasures. These might include a variety of types of detonations and kinetic energy maneuvers.<sup>25</sup>

In the interests of training for such missions, Daniel Durda of the Southwest Research Institute, Boulder, Colorado points out that there are some 10,000 near-Earth asteroids larger than 33 feet (10 meters) across that are easier to reach from an orbital energy standpoint than the surface of the Moon. Once at one of these non-threatening 10 meter class asteroids, a crew could examine its geology and test equipment for several weeks. The entire mission could take less than two months. This approach is "well within our experience base when you consider the stay times that we will become accustomed to for International Space Station (ISS) expeditions... It turns out that during the entire mission, the crew will never venture farther from Earth than about 4.5 lunar distances." Durda believes that development of human asteroid rendezvous capability will provide invaluable data as well as develop the skill set that will be needed to reliably divert an asteroid when a larger one does threaten all or part of Earth.<sup>26</sup>

Whether humans or space probes are sent to NEOs to perform countermeasures, Earth bound defense policymakers must become familiar with the orbital aspects of these space encounter scenarios. Chief among these are out-of plane dynamics. The obvious terrestrial-oriented response to an approaching NEO is to "deflect" it sideways so that it will miss Earth. This countermeasure would only cause the object to wobble in its orbit before it would still arrive at future points close to the original predictions. Instead, force should be directed along the flight path of an NEO, to slow it down from in front of its direction or to speed it up from behind.

This last countermeasure is akin to the downfield blocking penalty of clipping (pushing) from behind in American football, or slide tackling (tripping) in soccer. Both of these countermeasures alter the energy of the orbit, causing the asteroid to miss Earth. James Oberg, after presenting this idea at the United States Space Command then dismissed it by saying: "But try and explain this to someone unfamiliar with orbital operations. Tell them that in order to make it miss Earth, you want to SPEED UP the approaching asteroid, and see the reaction."<sup>27</sup>

This is not a legitimate reason to dismiss this idea. In addition to the "clipping" analogy, Oberg's countermeasure could be explained as equivalent to a quarterback correctly judging where a receiver will be when he throws a football (asteroid); then deliberately throwing too slow or too fast to that point, resulting in an "incompletion." This is an easy concept to communicate to policymakers worldwide, but only if the correct rhetorical devices are used. Around the world, "centering the futbol" could be substituted for "passing the football." Part of the problem in talking about

planetary defense at this point in time is cultural disconnect; not so much between nations, but between scientists and policymakers.

### **Summary of Existing U.S. Air Force Thought on Planetary Defense**

To avoid what General Worden calls the "political consternation" surrounding nuclear weapons as part of a PDR, Worden stresses the deployment of micro-satellites for detection and potential deflection of NEOs. For efficiency, Worden believes it makes sense to piggyback detection and cataloging efforts onto the DoD budget. At the same time, he sees an opportunity to engage in low cost micro-satellite rendezvous missions, as part of an international effort to characterize the composition and structure of all classes of NEOs, including comets.<sup>28</sup>

Worden's approach appears sound programmatically as well as diplomatically. In any international effort, it is always wise for a lead power to shoulder the burden of the groundwork while engaging in the more exciting work multilaterally. This is especially true if there are novel but effective alternatives for proceeding with the exciting missions, as there appears to be with micro-satellite technology. Renewed international enthusiasm for the United States as well as increased awareness of science among the American public might result from a focused international endeavor against the NEO threat.<sup>29</sup> Expanding the architectural analogy further, Worden seems to be the foreman, with blueprint in hand, who has already started building the lateral supports of the security dome and has invited others to join.

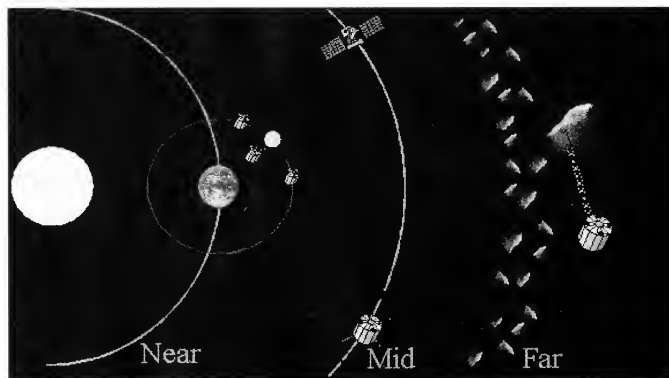
One of the first partners in building the dome of planetary defense is likely to be the European Space Agency (ESA), which is as familiar as NASA and the USAF with the body of published literature that exists concerning NEO mitigation counter-measures. ESA feels that for each possible scenario of an NEO impact, the best defense option should be determined in advance since the warning time before impact could be very short. Instead of predicting international resistance to a planetary security dome, ESA is likely considering the necessity for international cooperation. In a report prepared for the ESA by Dr. Christian Gritzner of the Institut für Luft-und Raumfahrttechnik, Technische Universität Dresden, Gritzner cites an excerpt from the report of the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (Declaration of Vienna, 1999), approved by the United Nations General Assembly. It reads:

[...] actions should be taken [...] to improve the international coordination of activities related to near-Earth Objects, harmonizing the worldwide efforts directed at identification, follow-up observations and orbit prediction, while at the same time giving consideration to developing a common strategy that would include future activities related to near-Earth Objects [...].<sup>30</sup>

The Air Force 2025 paper proposed an interesting and useful analogy for battle space management and space situational awareness that involves command, control, computers, communications and intelligence, otherwise known as “C4I.” The authors used the air defense network employed by the British during the Battle of Britain in 1940 as an example:

Many observers deployed along the coast of the English Channel scanned the skies for formations of German planes and, once detecting them identified their size and composition...relayed their information to the centralized command centers where the information would be integrated into the big picture with radar and other observations.<sup>31</sup>

To this end, the Air Force 2025 paper proposed three tiers of planetary defense sentinels or “gargoyles” in the cathedral analogy. Each tier or grouping of gargoyles would be developed sequentially from near to far. Detection systems would be deployed first and closer in to Earth, developed in parallel with C4I systems, followed by mitigation systems that would be deployed later and farther away from Earth. In regard to mitigation countermeasures, their proposal involved near tier use of nuclear warheads, mid tier use of space-based kinetic energy systems and far tier use of space-based laser systems as shown in the illustration.<sup>32</sup>



(Urias 1996).

**Illustration 2:** Three tiers of planetary defense.

General Worden might critique the Air Force 2025 paper by arguing that while the three tier defense (dome) adds sophistication to planetary defense planning, the “near tier” nuclear-warhead component of their proposal adds unnecessary international “political consternation;” when it is not clear that strike weapons are the best countermeasures against NEOs anyway. One exception to this might occur in a truly identifiable emergency in which a United Nations resolution authorizing the use of nuclear force against an inanimate object in outer space might be quickly negotiated.

## Conclusion and Recommendations

A PDR has a probable chance of reducing international insecurity if the main countermeasure agreed upon is alteration of the speed of existing flight paths of NEOs using non explosive means far beyond low Earth orbit before objects on ECOS become NEOs. A PDR should rapidly deploy re-directable micro-satellite sentinels beyond low Earth orbit to rendezvous with NEOs as far away from Earth as is feasible. The effectiveness of such a deployment will depend on the quantity, optical detection capability, data analysis and information dissemination capabilities of the NEO detection micro-satellites sentinels.

The likelihood that a PDR will be misused decrease as a PDR is constructed through engaged U.S. diplomacy which would increase transparency due to the fact that an increased number of micro-satellite sentinels would be deployed jointly by different key nation states. By not adding to terrestrial insecurity by any one country unilaterally constructing a planetary defense system, the PDR would complement the existing international convention on the authentication of NEO risk, the Torino scale that has been developed and in effect since 1999.<sup>33</sup>

This approach would reflect the original concept of transparency behind President Dwight D. Eisenhower's Open Skies initiative to the former Soviet Union (which they refused), concerning the joint deployment of military reconnaissance flight for arms control verification. The next challenge will be to revive and extend the Eisenhower precedent in a proactive manner against the NEO threat. This action would honor the sentiment and vision of the late Representative George Brown of California:

If some day in the future we discover well in advance that an asteroid that is big enough to cause a mass extinction is going to hit the Earth, and then we alter the course of that asteroid so that it does not hit us, it will be one of the most important accomplishments in all of human history.<sup>34</sup>

## Notes

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<sup>3</sup> Ibid.

<sup>4</sup> Jeff Foust, "Panel: NEO Search Efforts Need More Support," Spaceflight Now Online 12 July 2002. <http://spaceflightnow.com/news/n0207/12neo/>

<sup>5</sup> Brigadier General Simon "Pete" Worden (USAF). "Planetary Defense: A Military Perspective," *International Space Development Conference*. National Space Society, Denver, Colorado, 24 May 2002.

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- <sup>21</sup> Ibid.
- <sup>22</sup> John Urias, et al. Planetary Defense: Catastrophic Health Insurance for Planet Earth. Research Paper Presented to Air Force 2025. October 1996 <[www.au.af.mil/au/2025/volume3/chap16/v3c16-1.htm](http://www.au.af.mil/au/2025/volume3/chap16/v3c16-1.htm)>
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- <sup>25</sup> Webpage, "The Threat of Large Earth-Orbit Crossing Asteroids," Space Studies Institute, Princeton, New Jersey. [www.ssi.org/body\\_earth\\_orbit\\_crossing\\_asteroids.html](http://www.ssi.org/body_earth_orbit_crossing_asteroids.html)
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# Nature's Medicine Cabinet: Notes on Botanical Therapeutics at the Birth of the New World

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## Abstract

The period stretching from Columbus's first voyage in 1492 to the mid-seventeenth century was a formative period in the development of medicine, especially botanical therapeutics. This brief paper outlines the evolution of knowledge of medicinal plants during this period, which also saw the exploration of the New World.

## Old World Therapeutics

Therapeutics in the Old World underwent a deep transformation in the 16th and 17th centuries, developing from its classical and medieval roots in directions that led toward modern empirical science.

***The Medieval Legacy.*** As the 15th century ended, the field of therapeutics in Europe was largely dominated by Arabic pharmacy. From the end of the 11th century onward, Arabic medical treatises (including pharmaceutical works) had been translated into Latin in the scholarly centers of southern Europe (Salerno, Toledo, and Montpellier). These translations included many terms that were not translated but simply transliterated from Arabic, thus introducing uncertainty and confusion. This was particularly the case for technical terms and plant names. As a consequence, drugs, especially the Oriental ones previously unknown in the West, were not correctly identified by Western physicians and this gave rise to many mistakes.

Furthermore, Arabic pharmaco-therapy heavily relied on compound drugs. Their action was not as well known as was that of simple drugs: did it associate the properties of all the components or was it a new property, specifically produced by the association of the components? This ambiguity led physicians to hypothetically describe the action of compound drugs by reasoning rather than by clinical experience. Even more: physicians considered that such an action was unpredictable.

***Challenge by Early Humanists.*** After the Fall of Constantinople in 1453 brought about wider circulation of Greek texts in the West, such scientists as the Italian Nicolao Leoniceo began to compare Arabic, late medieval, classical Latin and

Greek therapeutic texts. Discovering similarities, Leoniceno concluded that not only the Arabic and medieval works, but also such a classical and authoritative Latin treatise as the encyclopedic *Historia Naturalis* by Pliny, in the first century A.D., were just epiphenomena of previous Greek literature and were characterized by innumerable mistakes, a deep incomprehension of the original texts, and a lack of first-hand knowledge of botany. This was all the more true, he concluded, because as works were passed along to later generations errors accumulated over time. As a consequence, Leoniceno considered that the exercise of therapeutics relying on classical Latin, Arabic and medieval Latin works exposed patients to danger. He recommended that all the non-Greek literature be ignored, and that medical practice should return to Greek therapeutic lore. His booklet, *De Plinii aliorumque in medicina erroribus* (*On the mistakes in medicine by Pliny and others*) first published in 1492 in Ferrara, provoked a harsh polemic by traditionalists.

**Medical Humanism.** In spite of the opposition to Leoniceno's thesis, Greek pharmaceutical literature was quickly reintroduced into contemporary European science. As early as 1499, indeed, the Venetian publisher Aldo Manuzio published the Greek text of the founding work of pharmacology, *De materia medica* by Dioscorides (1<sup>st</sup> century A.D.), which is an inventory and analysis of the natural substances of all kinds (but mainly vegetable) used therapeutically. While the Greek text of the work was republished five times during the 16th century (in 1518, 1529, 1529-1530, 1549 and 1598), it was also translated into Latin and printed as early as 1516 by the French doctor Jean Ruelle. This translation was also abundantly reprinted and plagiarized during the whole 16th century. The main purpose of this activity was philological: it aimed to recover a full command of the meaning of the text rather than to transform medical practice.

At the beginning of the 1530s, however, the interest in classical Greek pharmaceutical literature shifted from philology to botany. Scientists became interested in identifying the plants mentioned by Dioscorides. For the first time, they equated the plants described in *De materia medica* with those of Northern Europe. This was particularly the case of two of the so-called "German Fathers of Botany," Otto Brunfels and Leonhart Fuchs, authors, respectively, of the *Herbarum vivae eicones* (*Living plant pictures*), first published in Strasbourg, 1530, and *De historia stirpium commentarii insignes* (*Notable commentaries on the history of plants*) first published in Basel, 1542. The word *historia* (*history*) is significant: it does not refer to *history* as the account of past facts, but is used in the sense it has in Aristotle's scientific works and means *research, compilation of data on a topic*.

In a second phase, scientific efforts were directed at searching for the plants mentioned by Dioscorides in their original environment, the Mediterranean area. This was mainly the contribution of the Italian doctor Pietro Andrea Mattioli, who published first an Italian translation and then a commentary on Dioscorides' *De*

*materia medica*. With great energy, he constantly updated his work and repeatedly published new versions.

**From Erudition to Medical Practice.** As the re-appropriation of ancient therapeutic literature progressed, doctors gradually re-introduced into their practice the drugs, and their uses, that had been described in classical texts. This implied an examination of previous recipes, aimed at eliminating the problems and dangers of medieval therapeutics. A precursor of this movement of revision was the so-called *Ricettario fiorentino* published for the first time in 1498. Considered to be the first pharmacopoeia, the *Ricettario* was prepared by a committee of doctors commissioned by the City of Florence to ascertain the validity of medicines on the market and to recommend a list of safe preparations.

Later on, the Ferrara doctor Antonius Musa Brasavola, who was a student of Leonicensio, analyzed all the medicines prepared at that time by apothecaries, by types of preparations: *Examen omnium simplicium*, *Examen omnium syroporum*, *Examen omnium catapotium vel pilula*, *Examen omnium loch, id est linimentum* (respectively: *Examination of all simple medicines*, *of all syrups*, *of all catapotia or pills*, *of all loch, that is, unguents*) His works were published from 1536 onward with many new editions, legal and not. As a consequence, many traditional preparations were rejected, opening more widely the door to Greek classical lore.

**The Application of Ancient Methods to New Floras.** In a further phase, when the ancient Greek legacy was fully dominated by erudite philologists and gradually reintroduced into practice by doctors and apothecaries, its methods were carried beyond the classical Greek texts to describe and analyze other floras, drugs and medicines. Thus Dioscorides' method was transferred from Mediterranean to Central and Northern European flora and drug lore. A good example of this is the series of works by Rembert Dodoens, each of which is devoted to a category of plants: *De frugum historia* (*History of legumes*, Anvers, 1552), *Historia frumentorum* (*History of grain*, Anvers, 1565), *Florum et coronariorum odoratumque historia* (*History of flowers, wreaths and perfumed plants*, Anvers, 1574), *Purgantium ... historiae* (*Histories of purgative plants ...*, Anvers, 1574), *Historia vitis vinique* (*History of grape and wine*, Cologne, 1574).

At the same time, Dodoens also compiled a vast botanical synthesis, first published in two steps: *Trium priorum de stirpium historia commentariorum imagines* (*Illustrations of the first three commentaries on plant history*, Anvers, 1553) and *Posteriorum trium ... de historia stirpium commentariorum imagines* (*Illustrations of the next three commentaries on plant history*, Anvers, 1554). Then the two parts were published together: *Commentariorum de stirpium historia ... imagines novae* (*New illustrations of the commentaries on plant history*, Anvers, 1559). The final version is particularly famous for having been published first in Dutch under the title *Cruydeboek* (*Book of herbs*), in Anvers, 1554.

This change in the object of botany and pharmacy was understandingly accompanied by a gradual move of the center of activity from Italy, first to Southern France (Montpellier) and then to Northern Europe, Belgium and the Netherlands (Leiden).

**Botanical Gardens: a Teaching Tool.** In this progressive but rapid evolution of botany and pharmacy, a turning point was the creation of new botanic gardens in Pisa and Padua in 1542 and 1543 respectively. Such gardens were not a novelty. Since the early Middle Ages, indeed, monasteries had created botanic gardens for the cultivation of the medicinal plants used for the treatment of sick monks and people. The new element in these Italian creations was their link with university teaching. Botanic gardens were conceived as teaching instruments, to make it possible for medical students personally to know the plants to be used for therapeutic purposes. The study of plants was no longer limited by season and location, but was more widely available. This was all the more true when fresh plants were dried (*hortus siccus*). Furthermore, botanic gardens enabled botanists to acclimate non-native plants. In all these ways, botanic gardens transformed teaching activity and, hence, knowledge of plants, enhancing the practice of therapeutics.

From Italy, this new model of teaching relying on direct observation of plants was transferred to Southern France (the University of Montpellier) by Archbishop Guillaume Pellicier, the ambassador from King François I to Venice, who lived in the *Serenissima Repubblica* from 1539 to 1542. With Guillaume Rondelet, teaching of botany in Montpellier thus included field expeditions to directly observe plants in nature. This new kind of medical education attracted students from all over Europe, who later duplicated this model in their native countries. Among these students, there was the Swiss Felix Platter, who created the botanic garden of Basel, and Charles de l'Ecluse, who succeeded Dodoens in 1593 as a professor of botany at the University of Leiden, newly founded in 1575. In 1587 a botanic garden was founded at Leiden and the university became very rapidly the botanical center of Europe. New botanic gardens were created later: Oxford in 1621, the *Jardin des Plantes* of Paris in 1626, Uppsala in 1665 and the Chelsea Physic Garden of London in 1673.

### Medicinal Botany in Spanish and English Literature

The rapid re-assimilation of ancient botanical and therapeutic literature and their re-insertion into practice led, as early as the 1540s, to an abundant literature in vernacular languages. Brunfels and Fuchs first published their works in Latin: *Herbarum vivae eicones* (*Living plant pictures*, Strasbourg, 1530), and *De historia stirpium commentarii insignes* (*Notable commentaries on the history of plants*, Basel, 1542), respectively. Further on, they translated them into German: *Contrafayt Kreüterbüch* (*Book of herbs*, Strasbourg, 1532), and *New Kreüterbuch* (*New book of herbs*, Strasbourg, 1543).

Jerome Bock, instead, first published his treatise in German: *New Kreütter Buch* (*New book of herbs*, Strasbourg, 1539), and translated it into Latin later on: *De stirpium commentariorum libri tres* (*Three books of commentaries on plants*, Strasbourg, 1552). At about the same time, a first Italian translation of Dioscorides' *De materia medica* was published in Venice, in 1542, to be followed shortly by the first edition of Mattioli's translation, also in Venice, in 1544.

In the Spanish world, Dioscorides' *De materia medica* was translated into Castilian by Andres de Laguna. Like Mattioli's, this translation included an abundant commentary on the text aimed not only at identifying the plants, but also – if not primarily – at ascertaining their therapeutic properties. First published in Anvers by Jean de Laet in 1555, the work was then printed in Salamanca, first in 1563 and no less than four other times before 1586. During the same period, Juan Jarava translated into Castilian Fuchs' *Historia stirpium* (*History of plants*): *Historia de yerbas y plantas* (*History of herbs and plants*), in Valencia, 1557.

Laguna's translation of Dioscorides' *De materia medica* remained a reference in Spain until late in the 18th century. Fifty years after the last Salamanca edition (1586), it was reprinted in Valencia in 1635 and reprinted another four times before 1695, with yet another edition in Barcelona in 1677. Then it was printed in Madrid in 1733 and reprinted three more times by 1783.

In England, the first herbal to be printed was *The Grete Herball* (London, 1526), which was a translation of the French version of the medieval *Herbarius*. The first original work on medicinal plants was the herbal of William Turner, published in several parts: the first part came out in London in 1551, and the second and third in Cologne in 1562 and 1568, with a reprint of the whole work the same year, also in Cologne (*The first and seconde partes of the Herbal ... lately oversene corrected and enlarged with the Thride parte lately gathered and nowe set oute withe the names of the herbes in Greke Latin English Duche Frenche and in the Apothecaries and Herbaries ...*). The work was illustrated with plant representations that reproduced the tables of Fuchs' *De historia stirpium*.

Continental scholarship was further assimilated into the English speaking world with Henry Lyte, who in 1578 published the first edition of his English translation of Dodoens' *Cruydebock* (*A nieuwe herball*) made from the French version of the work. Then, in 1577, John Frampton published a version of Monardes' complete works under the title *Joyfull newes out of the New-Found Worlde*. Twenty years later in London there appeared the *Herbal* of John Gerarde. Mainly relying on Dodoens' herbal, it also compiled material from other previously published works, be it the herbal by Turner or other Continental herbals such as those of Jakob Theodorus Tabernaemontanus, Pierre Pena and Matthias de L'Obel. Full of errors of all kinds, the work was corrected by L'Obel until Gerard stopped the revision. It was not republished until 1633, when it was revised by Thomas Johnson, assisted by John

Goodyer, author of an English translation of Dioscorides' *De materia medica* that remained unpublished. Almost simultaneously (1597) William Langham published a similar compilation on medicinal plants: *The garden of health containing the sundry rare and hidden vertues and properties of all kindes of simples and plants. Together with the manner how they are to bee used and aplyed in medicine for the health of mans body ... Gathered by the long experience and industry (...).*

### Discovery of the New World's Therapeutic Resources

After Christopher Columbus reached the New World in 1492, Spaniards quickly understood that the newly discovered continent was full of invaluable resources, not only gold and precious stones, but also medicinal plants. As early as 1518, Paulus Riccius, Court Physician to the Emperor, realized that the bark of a small tree found on the North coasts of South America, guaiacum (*Guaiacum officinale* L.), had diuretic and laxative properties. He had obtained its bark during a mission in Spain and shared it with a German physician, Ulrich von Hutten, who in turn used it successfully to treat syphilis. In 1519 von Hutten celebrated the efficacy of the plant in a small treatise entitled *De guaiaci medicina et morbo gallico* (*On the French diseases and its treatment by means of guaiac*) printed in Mainz by Johann Schoeffer.

Tobacco (*Nicotiana tabacum* L.) was known by Colombus from his first voyage to the New World. Used in medicine to treat "blotches" according to Gerard's Herbal (1597), it was cultivated by European settlers from 1531 onward, and traded to Portugal beginning about 1548. In 1561, it was brought to the French Court by Jean Nicot, the ambassador of the French kings François II and then Charles IX to the Court of the Portuguese king Sebastiao.

After these first discoveries, importing plants from the New World became gradually more important. All such products identified and shipped by Spaniards arrived in the harbor of Sevilla. There, in the mid 1500s, Nicolás Monardes collected all kinds of plant products from the ships as they arrived, and analyzed their therapeutic properties, using the concepts and methods of contemporary botanical and pharmaceutical systems. In 1565 he published in Sevilla the results of his investigations in his *Dos libros, El uno trata de todas las cosas que traen de nuestras Indias Occidentales, que sirven al uso de medicina y como se ha de usar de la rayz de Mechoacan, purga excellentissima. El otro libro, trata de dos medicinas maravillosas que son contra todo veneno, la piedra bezaar, y la yerva escuerçonera. Con la cura de los venenados. Do veran muchos secretos de naturaleza y de medicina, con grandes experiencias.* (Two books. One deals with the products brought from our Western Indies, which are used in medicine, and with how to use the Mechoacan root, an excellent purgative. The other book deals with all the marvelous medicinal products that are against all venoms, the bezoar stone and the escuerçonera herb.

*With the cure of victims of venom. From which will come many secrets of nature and medicine, with many great experiences.)*

In spite of Monardes's claim to describe all the products coming from West Indies, the work was necessarily incomplete. A first attempt toward a systematic inventory of traditional New World Indian therapeutic lore was made by Martin de la Cruz in collaboration with Juannes Badianus. In 1552 these two Aztec Indians, who had been educated in a Spanish Catholic school, compiled in both Latin and Aztec a list of diseases known to Aztec natives and the therapeutics traditionally used to treat them. The text was illustrated with 204 representations of plants. The manuscript, now owned by the Vatican Library—the so-called *Badianus* manuscript—was sent by the Vice-Roy of India, Don Francisco de Mendoza, to Charles V, King of Spain and Emperor of the Holy Roman Empire.

Yet this valuable first hand report does not seem to have been used at the Spanish Court. It was not until 1570 that a systematic inventory of the New World resources was planned. In that year Felipe II, King of Spain and Emperor, sent Francisco Hernández to the New World with the mission of gathering from local populations everything they knew about the natural resources of the New World. After three years of field work (February 1571 – March 1574), Hernández wrote his massive *Historia de las Plantas de Nueva España*.

Meanwhile, Orta had fled to India to avoid the Catholic Inquisition, and began studying India's traditional uses of medicinal plants. He discovered that they were very similar to those of classical Greek authors. Greek classical medical and therapeutic texts had been translated into Arabic during the 9th century A.D., and then diffused through the whole Arabic world, including India. In Goa, Orta created a printing press and printed his work in 1563 under the title *Coloquios dos simples, e drogas he cousas mediçinais da India, e assi dalgumas frutas achadas nella onde se tratam algumas cousas tocantes a mediçina, pratica, e outras cosas boas, pera saber ...* (*Conversations on simples, drugs and medicinal products from India, and also on some fruits ... where it is dealt with some things related to medicine, practical, and other things good to know ...*).

The Portuguese Cirstobal Acosta met Orta in India, brought Orta's work back to Spain and translated it into Spanish. Costa also published another work, in which he plagiarized Orta's *Coloquios*, though he added some new data and representations of plants.

Unfortunately, these systematic and organized efforts had little or no impact on therapeutics—the European range of drugs was not transformed, nor did the colonial troops and settlers in the New World absorb and use local medicinal resources. The case of Hernandez' encyclopedia is significant: the 38 volumes that the *Protomedico* brought to Spain contain copious information about plants, along with dry specimens and plant representations. However, all this material was left unstudied in the King's

library at El Escorial until King Felipe II, in 1580, commissioned his personal physician, the Italian doctor Antonio Recchi, to prepare an abridged version. A Castilian translation of this short version was published in Mexico in 1615 by Francisco Ximenez (the Latin original text was not printed until 1651 in Rome). Hernandez' full manuscript was destroyed in the fire that ravaged the Escorial in 1671.

French, Dutch and English settlements in North America came later than the Spanish explorations. They did not substantially contribute to the knowledge of the natural medicinal resources of the New World, being more oriented toward trade. The Virginia Company settled Jamestown in 1607. There, tobacco was successfully cultivated from 1612 onward and traded to England seven years later. The Pilgrims, arriving on the *Mayflower* in 1620, largely modeled their daily life – including their therapeutic practices – on those of their homeland, all the more so because, in a first phase at least, their subsistence was shipped from the Old World.

In their transfer to the New World, colonists at first merely continued their previous practice of therapeutics. According to a theory that had a certain success in a period of national rivalry, people had to use the typical resources of their own natural habitat, particularly the plants, which were supposedly provided with specific properties to treat local diseases (i.e., those from the region of their birth). Already illustrated by the French doctor Symphorien Champier in his *Rosa Gallica* (Paris, 1514), the theory was repeated just before the beginning of the English colonial enterprise by an Englishman Timothy Bright, in the *Treatise wherein is declared the sufficiency of English medicines ...* (London, 1580).

Settlers' drug lore was not, however, strictly limited to the resources of their native area, but included the European common flora. This was all the more so because texts circulated all across Europe, first in Latin and then in vernacular translations. They created a common botanical and therapeutic knowledge, determined by the equation of local flora and therapeutic practices with those of previous works, be it ancient Greek treatises or more recent texts rooted in the classical tradition. Exchange of plants between the members of what has been rightly called "the Republic of Botanists" created this feeling of community and the unity of therapeutic lore.

The species transferred by colonists to the New World and acclimated there for therapeutic purposes thus were those described in herbals diffused throughout Europe, from the medieval *Herbarius* to Laguna and most recent English works, be it original treatises or translations.

### The Underlying "Science"

Therapeutic use of plants relied on a tradition dating back centuries, if not millennia. Knowledge was probably gained empirically by trial and error from the dawn

of Mankind onward. Across time and across cultures, people ate certain plants or brushed against certain plants and observed that these actions had certain effects – for good or ill. Ultimately, a body of lore grew up, the plants were named, the effects codified, and certain plants were routinely paired with the amelioration of specific conditions. Later on, this kind of science was recorded by learned physicians. In the Western World, this was not the case until Hippocrates and his followers, the so-called Hippocratic physicians, authors of the sixty treatises ascribed to Hippocrates himself, but written from Hippocrates' period to the 2<sup>nd</sup> century A.D. From this epoch onward, previous empirical knowledge was theoretically analyzed according to different systems. One of the most striking, was atomism applied to medicine (ca. 1<sup>st</sup> century. B.C. – 1<sup>st</sup> century A.D.). This said that the therapeutic efficacy of drugs results from an exchange of particles between the drugs and the substance of the body.

Fundamentally, two systems prevailed: holism and materialism. Their general conceptual framework was provided by the so-called theory of four elements. The entire universe (the cosmos) was supposedly made up of four elements associated in couples (earth and air, water and fire) that had opposite qualities (heavy and light, moist and dry). These elements and qualities combined to produce the basic fluids of life—blood, phlegm, yellow and black bile—themselves associated with specific organs. Disease was due to a disequilibrium in the nature or quantity of these fluids. Therapeutics thus consisted in restoring the original equilibrium. Its basic principle was the law of the contraries (*contraria contrariis*). Concretely, a deficiency or alteration of a vital fluid of the body had to be counter-balanced by a re-injection of this fluid by means of therapeutic substances.

According to holism, the therapeutic activity of natural substances—mainly, but not only, plants—resulted from their inter-action with the four elements that constituted the world. For example, a plant was considered calefacient because it was particularly exposed to the sun and assimilated its warmth as if it was an element it could capture. According to materialism, the action of therapeutic substances results from exchanges of particles as described above. During antiquity, holism was mainly represented by Dioscorides' *De materia medica* and materialism by Galen's works such as *De simplicium medicamentorum temperamentis et facultatibus* (*On the mixtures and properties of simple medicines*).

Galen's system constituted a complicated association of material of different origins. According to it, indeed, therapeutic substances contained not one, but two properties—in fact, a couple of opposites. Hence, the title of his work: *On the mixtures ... of simple medicines*, where mixture refers to the association of two opposite qualities in each matter. This association of properties was measured on a double scale of four degrees (one scale for each of the two opposite). As a consequence, the zero degree did not represent the absence of the two opposite qualities,

but their equilibrium. On the other hand, Galen's system relied on a certain form of materialism: the properties of therapeutic substances and their dynamic within the body was explained by the weight and structure of the particles the substances were made of.

Galen's therapeutic theories were not widely diffused in Byzantium, nor in the Middle Ages. In the Arabic World, however, they were greatly praised and constituted the specific reason why Arabic physicians could not determine the final property of compound medicines: if, indeed, an ingredient of a compound medicine associated two opposite qualities, what is the final property of the medicines that contain it?

This type of speculation was transmitted to the late Middle Ages from the 12th century A.D. onward and further preserved and transmitted, so that they dominated the field of therapeutics in the Renaissance, even though such a classicist as Leonico fought to reject the influence of Arabic science and to return, instead, to Greek pharmacology, specifically, Dioscorides' holism. He did not fully succeed in his attempt, however. Therapeutic practice remained largely influenced by Arabic preparations.

While erudite physicians were involved in academic discussions and polemics, traditional healers continued to practice empirical therapeutics. They used remedies transmitted to them from the most remote past without any other justification than that they were told such remedies worked and that they did. The best example was the use of foxglove to treat cardiac pathologies by a traditional English healer, whose secret William Withering revealed in his 1785 *Account of the Foxglove, and Some of Its Medical Uses*.

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